CHARACTERIZATION AND UTILIZATION OF SOLID WASTES GENERATED FROM BHILAI STEEL PLANT

M. Tech. (Res.)

Synopsis

by

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Under the Supervision

of

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DEDICATED TO MY PARENTS.

CERTIFICATE

This is to certify that the Thesis entitled "**Characterization and Utilization of Solid waste generated from Bhilai Steel Plant"** being submitted by Nirlipta Priyadarshini Nayak for the award of Masters' Degree in Engineering to the National Institute of Technology, Rourkela, Orissa, India is a record of bonafide research work carried out by her under my supervision and guidance. The Thesis, in my opinion, has fulfilled the requirements of the regulation of National Institute of Technology, Rourkela and has satisfied the standard pertaining to the Degree. The results incorporated in the Thesis have not been submitted to any other University or Institution for the award of any Degree or Diploma.

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CONTENTS

Subjects	Page

CHAPTER-6

6. UTILIZATION OF WASTE

CHAPTER-7 SUMMARY & CONCLUSION

REFRENCES

Chapter-I

INTRODUCTION

1. INTRODUCTION

Development of any country is largely based on its magnitude of industrial growth.India after independence laid stress on industrial revolution. Of different industriesSet up, steel industries took a leading role in the world over during mid-sixties.BhilaiSteel Plant (BSP) was the first of its kind under public sector set up in India.BSP hasbeen producing steel and other products over last 4 decades.However, in a steelindustry where a number of manufacturing processes are employed involving use ofvarious raw materials and in-process materials, it is but natural that many seeminglyvalueless substances are generated which can be termed as waste materials (Table1.1) The aspect of waste management at various levels from mines to smelters hascaught the attention of technocrats, mineral economists,planners&the consumers .Today the management of mineral commodities has valuable waste ofvarious nature at its disposal, which assume paramount importance and need to bedealt with in a judicious& sustainable manner.

Waste management involves management of such materials which have apparently no value. But prior to its management, proper characterization of wastes through physical, mineralogical and chemical analysis is very important because, if the composition is not exactly known, the “Eco saving” to be gained by the utilization of rejects can be lost. With the scenario changing, on passage of time and with the technologies getting regularly upgraded, there is need for use of such waste materials continuously being produced in large quantum through conversion of work materials to either by-products or in-process material for recycling.

Before stating the problem undertaken in this research programme and Scope thereof, the subject is introduced through presentation of global steel industry scenario, brief outline of Bhilai Steel Plant (BSP), causes and effects Of waste products generated in the steel industries for their classification, characterization and utilization etc.

1.1. Steel Industry Scenario

Steel is an alloy of iron with varying amounts of carbon and some other elements such as Manganese, Chromium, Nickel, Molybdenum, Zirconium, Vanadium, Tungsten and so on. Currently there are over 3000 catalogued grades of steel available. The global steel production touched 109.3 million tones in the year 2007 making an increase of 7.6% compared with 2006.The largest steel producing countries are China,Japanand United States, each of which produces around 100M.T.The largest consumers are Singapore (1,200kg), Taiwan (over 970kg) and Korea (830kg) per capita.India's steel production ranked 7th in the world in the year 2006, up from 9th in the year 2006. .

A look at the past production figures over the last century attests a significant shift in the geography of Steel making.In 1990, USA was producing 37% of the world steel as against 14% at present.With post war industrial development Asian production now accounts for almost 40%, Europe (including the former Soviet Union) for 36% and North America for 14.5%.Since the late 1960s there has been a leveling off of the rate of growth in steel production, which is partly attributable to greater efficiency in the use of steel and less wastage.Progress in steel making is also indicated from the ues of Bessemer converter at the turn of the 19th century to the introduction of oxygen conversion processes in the 1950s and continous casting in the 1960s.Steel is one of the most recycled non-expendable industrial materials recycled. material is used in all steel production.Even after decades of use, steel is salvaged and over 40% of steel production is based on recycled material including scraps.

The major steel producers in India are SAIL, TISCO, RNIL, Essar, Ispat Alloy, Jindal Lloyds and Usha Group.The seven integrated steel plants are:-

(1)Tata Steel Company
(2) Bhilai Steel Plant (BSP)
(3) Bokaro Steel plant (BSL)
(4)Rourkela Steel Plant (RSP)
(5)Durgapur Steel Plant (DSP)
(6) Indian Iron &Steel Company (IISCO
(7) Vishakhapatnam Steel Plant (VSP)

The Ninth five –year plan approach paper of Government of India has assumed the growth rates of steel demand during IXth and Xth periods at 8.85% and 8.25% respectively.As per the current forecast, the steel demand is expected to rise to 50million tones by end of Xth plan(2007 AD)

1.2. Bhilai Steel Plant (BSP)-An Overview

The Steel Authority of India Limited (SAIL) ranking 17th during 2005 and 19th during 2006 amongst the largest steel producing companies in the world, is the largest corporate entity in India.It is also one of the NAVARATNAS of India, with an annual production capacity of 12M.T. of crude steel, through its five integrated plants in Bhilai, Durgapur, Rourkela, Bokaro and Burnpur.It has three alloy and special steel plants at Durgapur, Salem and Bhadravati.The company's main steel products include flat (coils, plates and sheets) structural (angles, bars and rods) rail (high conductivity rails, light rails and heavy rails) and tubular products (welded pipes).While steel is SAIL's core product, it also makes ferro alloys, coal base chemicals, tar products, light oil and fertilizers.The company markets its products through a countrywide network of stockyards and distribution centres.It has well equipped research and Development Centres for Iron and Steel (RDCIS) at Ranchi, which can easily be described as one of the biggest of its kind for any steel industry in the world. SAIL has nine iron ore, five limestone, three dolomite and three coal mines grouped under its Raw Material Division (RMD) at Kolkata.

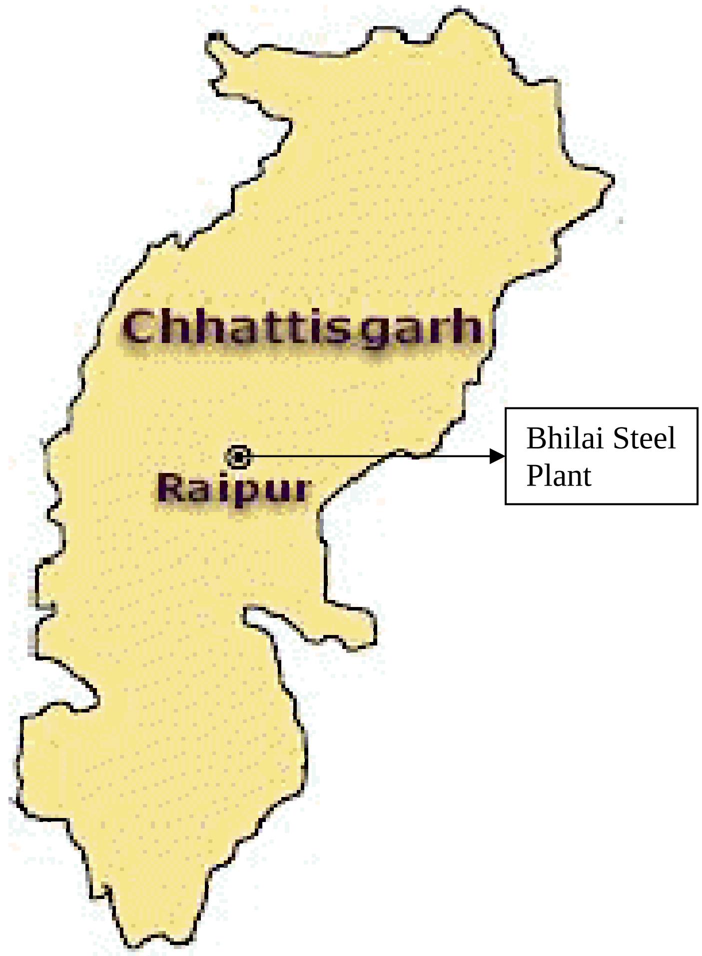
Bhilai Steel Plant (BSP) the major producer of a diversified range of sophisticated steel products, is a unit of SAIL with four decades in steel making. BSP stands testimony to the spirit of modern India and the age of technology marvel.

Bhilai Steel Plant –a symbol of Indo-Soviet techno-economic collaboration, is one of the first three Integrated steel plants set up by Government of India to build up a sound base for the industrial growth of the country.The aggrement for setting up the plant with a capacity of 1M.T.of ingot steel was signed between Government of erstwhile U.S.S.R. and India on 2nd February, 1955.Thereafter the plant was expanded to 2.5M.T. capacity per year, and then to 4MT of crude steel per year, with

Soviet assistance.Bhilai Steel Plant is located 40 kms west of Raipur, the capital city of Chhatisgarh, along the Howrah-Mumbai railway line and the Great-Eastern highway.

BSP is the sole manufacturer of rails and producer of the widest and heaviest plates in India.A major exporter of steel products, Bhilai produces 5.05 M.T. of crude steel annually, though its capacity is 4.0 M.T and for the year 2010, the projected production is 7.5M.T.The plant is the sole supplier of the country's longest rail tracks of 260mtrs.Bhilai specializes in the high strength UTS 90 rails, high tensile and boiler quality plates, TMT bars and electrode quality wire rods.It is a major exporter of steel products with over 70% of total exports from Steel Authority Of India Limited being from Bhilai.Bhilai Steel Plant, today, is a panorama of sky-scraping chimneys and blazing furnaces as a modern Integrated steel plant, working round the clock, to produce steel for the nation. Bhilai has its own captive Mines spread over 10929.80 acres. Iron ore requirements are met by Rajhara group of mines, 85kms South-west of Bhilai.Limestone requirements are met by Nandini mines, 20kms north of Bhilai and Dolomite comes from Hirri in Bilaspur dist., 135 kms east of the plant.

Bhilai expanded its production capacity in two phases-first to 2.5MT which was completed on sept 1, 1967 and then on to 4MT which was completed 1988.The plant now consists of ten coke oven batteries.The 7 metre tall fully automated batteries no 9 &10 are among the most modern in India.The first coke oven battery was commissioned on 31st January, 1959



FigI.1**: Location map of Bhilai Steel Plant**

Steel is made through twin hearth furnaces in Steel Melting Shop I as well as in through LD Converter –continous casting route in SMS II.Steel grades confirming to various national and international specifications are produced in both the melting shops.Production of cleaner steel is ensured by flame enrichment and oxygen blowing in SMS I while secondary refining in vaccum Arc Degassing ensures homogeneous steel chimneys in SMS II.The first Twin Hearth Furnace (at SMS I) was commissioned on 12th Sept,1986.

Bhilai Steel Plant is having various process units like-(A) Ore Bedding and Bending plant (B)CokeOvens(C) Sinter plant I , II & III (D) Blast Furnaces 1,2,3,4,5,6 & 7.(E)Steel Melting Shop I & II (F) CCM I &II (G)Plate Mill (H)Hot Strip Mill (I)Cold Rolling Mills (J) Sillicon Steel Mills etc.It produces diversified range of sophisticated steel products like HR Plate /Chequred Plates , HR Coils /Sheets , CR Coils / Sheets, GP / GC Sheets ,ERW pipes ,SW pipes ,Tin plates ,CRNO Coils /sheets etc. Different process units with material flow and diversified end products are shown in Fig 1.2.

To back this up , there are two captive plants with a generating capacity of 110MW ,Two oxygen plants, Engineering shops, Machine shops and a host of other supporting agencies giving Bhilai a lot of self-sufficiency.The power plant II of 74MW capacity has been divested to a 50:50 SAIL /NTPC joint venture company.

Not content with the quality assurance system for production processes, Bhilai has gone in for ISO 14001 certification for its Environment Management System and its Dalli Mines.Besides environment-friendly technology like Coal Dust Injection system in blast furnaces, de-dusting units and electrostatic precipitators in other units, BSP has continued a vigorous afforestation drive, planting trees each year averaging an impressive 1000 trees per day in the steel township and mines.

A leader in terms of profitability, productivity and energy conservation, BSP has maintained growth despite recent difficult market conditions, Bhilai is the only steel plant to have been awarded the Prime Minister’s Trophy for the best integrated steel plant in the country five times in the last seven years.

1.3. Waste Generated In Steel Industry: Causes &Effects

1.3.1. Cause of Waste Generation

The Steel industry is considered as resource intensive and pollution prone. Production of steel Involves several operations. It starts from naturally occurring raw materials like coal, iron ores# &fluxes to Produce hot metal in blast furnace, convert hot metal into steel and subsequently to go for rolling of steel Into finished product. Several other activities including production of refractory are also performed in Varying magnitude inside the steel works. A large quantity of waste is generated as a sequel to such Activities. To make one-tonne of crude steel even with good raw materials and efficient operation, 5 tonnes of air, 2.8 tonnes of raw materials and 2.5 tonnes of water are required. These will produce in addition to 1 tonne of crude steel, 8 tonnes of moist laden gases and 0.5 tonne of solid wastes [Lean, 1990]. However, in SAIL plants, this figure varies from 820-1,200Kg/tonne of crude steel—which is very high [Prothia and Roy, 1993]. In a steel industry, all the three types of waste materials (gaseous, liquid and solid) are generated. The generation of gaseous waste material is the highest but the management of solid waste material is the most intricate. The steel plants of the seventies were characterized by higher waste generation rates associated with massive dumps around the steel works resulting in serious land, water and air pollution.

Over the years, due to technological changes in steel making and strict environmental regulations and legislation , emphasis on raw material quality and emergence of new markets coupled with innovative ideas of waste reduction and rescue have resulted in drastic reduction in the quantity of waste generated in steel works from 1,200 Kg to less than 200 Kg per tonne of crude steel and recycling rates have reached 95-97% in some parts of the world. However, the solid waste generation presently in Indian steel industry is in range of 600-1,200 Kg/tonne of crude steel and recycling rate varies between 40- 70% which lead to higher production costs, lower productivity and further environmental degradation.

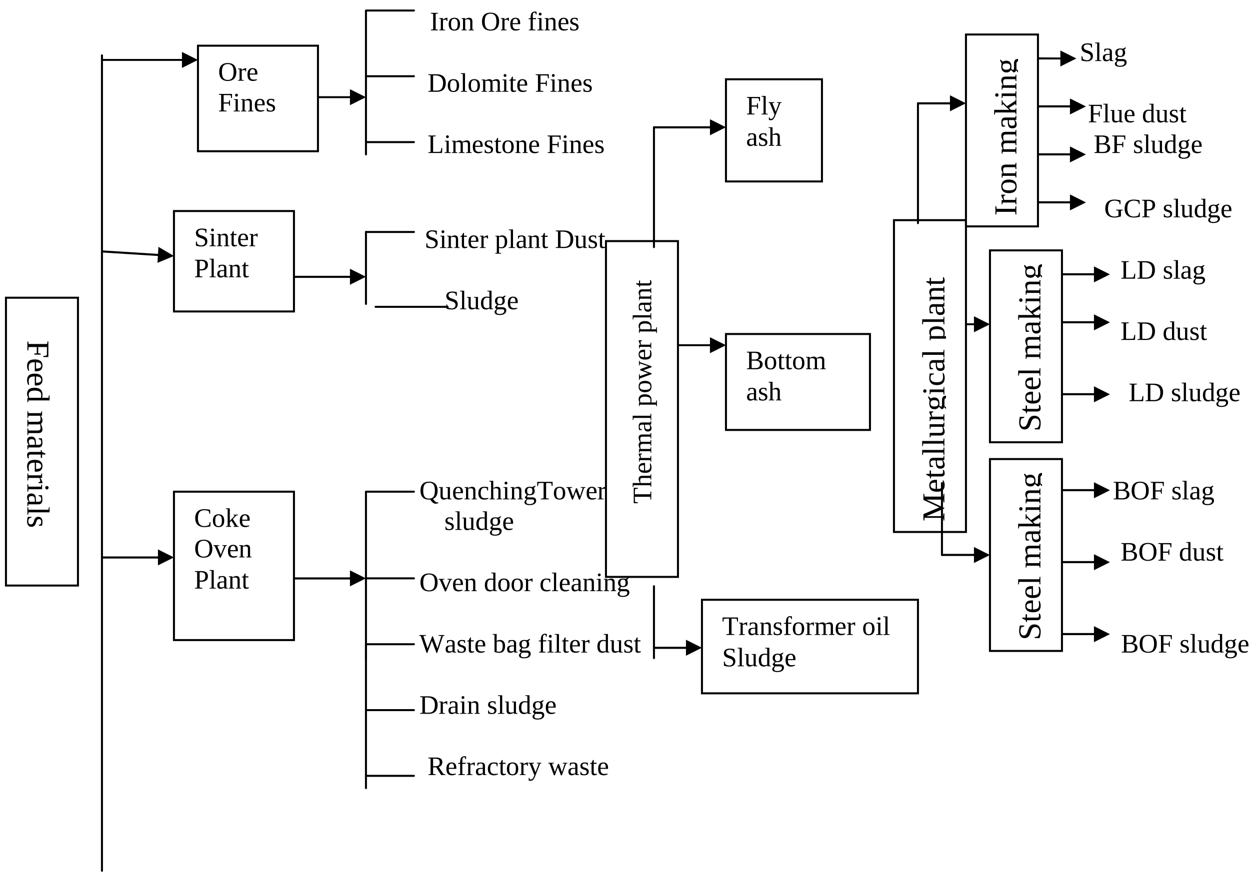


Table 1.1: Types of solid waste generates in an integrated steel plant

The generation quantity of various types of waste materials differ from one steel plant to another depending upon the steel making processes adopted and pollution control equipment installed. Generation and utilization of major solid wastes from process units and pollution control equipment in case of SAIL (Steel Authority of India Limited) as a whole vis-à-vis other developed countries is given in Table 1.2.

Table 1.2: Generation rate and utilization of solid waste

	Generation (Kg/Ton of Crude Steel)		Utilization	
	Other Develoed countries	**SAIL**	**Other Developed Countries**	**SAIL**
A.Process Waste				
1.Coke Breeze		80	-	100
2.BF Slag	210-400	445	100	59
3.SMS Slag	75-145	162	60-90	35
4.Mill Scale	20-25	25	100	100
5.Refractory waste	5-6	8	-	59
B.Pollution control Equipment waste				
1.Sinter plant Dust/Sludge	-	37	100	100
2.BF Fludust	5-11	22	100	60
3.BF GCP Sludge	4-8	12	30-74	1
4.SMS Slucge/Dust	7-15	10	100	37

For the year 1998-99; IISI Solid waste Report.

Table 1.3: Environmental impact due to various activities in an integrated steel plant

Sl No	**Activities**	**Environmental Impacts**
1	Mining	Dust generation, Air pollution, Noise pollution, Water logging
2	Melting & Refining	Air pollution, land pollution, Solid waste generation
3	Casting	Air pollution, Noise pollution
4	Processing	Vegetation, Water pollution, Domestic Animals, Dental and Bone Damage.

For easy understanding, the steel plant solid waste have been broadly classified into categories:

(a) Solid waste generated from process units.

(b) Solid waste generated from pollution control equipment.

Generation of solid waste from process units mainly depends on quality of raw materials and technology adopted. The primary reason for high waste generation in Indian steel Industry is the poor quality of raw materials I;e Iron ore and coal. High ash content of coal leads to increased coke consumption in blast furnace causing increased slag generation. Further, higher ash content of coal leads to increased fly ash generation in power plant. The high alumina content of iron ore increases the coke rate volume in blast furnace. Technological and operational discipline can bring down hot metal's silicon and sulpher level, which will in turn reduce the slag rate per tonne of crude steel. Other technological improvements like high blast furnace temperature, higher top pressure; use of prepared burden, injection into blast furnace etc will reduce the coke consumption rate which will ultimately reduce the slag volume. Similarly, continuous charging technologies for electric arc furnaces can reduce the volume of dust discharge by as much as 40%.Scrap in the pre-heater traps the dust and returns it to the furnace thereby increasing the steel yield. By adopting Electric Arc Furnace (EAF) of steel making the solid wastes generated from blast furnace process will be drastically reduced constituting major quantum of solid waste generation from an integrated steel plant. Similarly the COREX iron making process eliminates the need for coke making and coke oven gas by product recovery plants.

Solid wastes generated from process units are generally characterized by their uniform size and composition, low moisture content and high levels of Fe, Ca, C etc., which makes these waste suitable for recycling within the plant premises or to be sold out to consuming industries.

Solid waste generation from pollution control equipment mainly depends on type of control equipment i.e. dry/wet, efficiency of the equipment and quality of raw materials. To improve the work zone air quality , highly efficient deducing systems have been installed to capture secondary emissions that were previously discharged to the environment. This environmental protection measures relating to air and water lead to the accumulation of sludge and dusts rendering their reuse cumbersome. These dusts and sludge coming out of the pollution control equipment are grouped under hazardous waste [Unpolished IISI Report]. Pollution control measures can make the recycling of certain substances impossible due to their fine to ultra fine grain size. Dusts and sludge generated from flue gas and pollution control units vary in size and composition.

1.3.2. Effects on Environment

The process of industrialization and continous exploitation of earth resources for sustainable growth of civilization has depleted the non-renewable resources of the earth thereby adversely affecting the environment.

An integrated steel plant unit exhausts several harmful dusts, fumes and substances that are quite injurious to human health, vegetation, crops, landscape, animals, machine life etc. Such discharges contaminate and damage inland waters, environment, soil, food, human settlement and even flora and fauna. Therefore, these wastes could not be left uncared for and that is why thresh-hold limits for such harmful substances have been fixed and industries are required to adhere to these norms. The environmental impact due to steel production is given in Table 1.3.

1.4. Need for waste classification, characterization, & utilization

The subject of waste is an offshoot of inefficiency on any process. Nature knows no waste. Laws of nature govern the transformation of materials from one state to other. We ascribe the ideals of waste to a given situation according to our intents and purpose. Something unwanted or un-useful is taken as waste. But something unwanted in one situation may be of value in another and unusable in one trade may profitably be used in some other trade. It is left to human brain to devise ways and means, open new vistas of industries and develop new technologies to gainfully utilize the seemingly waste items. Generation of by-product is inevitable in all mining and industrial activities. So long as their intrinsic values and scope of utilization are not understood, these remain as waste or discarded materials and pollutants.

The U.N. conferences held at Stockholm in June, 1972 on human environment and the earth summit at Rio de Janrro held in 1992 have emphasized the need for sustainable development during exploration of mineral resources as well as regulation of these activities. In recent years, stringent legislation has been introduced for systematic and planned mineral development ensuring minimum damage to environment. With growing environmental awareness, the subject of waste management in a cost effective and eco-friendly perspective is gaining foot for protection of environment and derivation of value added wealth from waste. Moreover, the steel industry globally has shifted its focus from “end of pipe collection emissions” to “internal pollution prevention measures”.

Management of various types of solid waste in a steel plant is complex one. Though the basic approach is to explore the possibilities of recycling, enrichment and additional treatment within the production system, it is often not easy to integrate these in a well-established process flow sheet. Many technological developments and R & D investigations are now in progress in different parts of the world for utilization of the by-product waste materials. The immediate advantages of such recycling are:-

(a)Lower specific consumption of basic rew materials; (b) Lower production cost

(c) Higher product yield and ; (d) Lesser pollution and better environment.

These solid wastes, having wide-ranging impact on the environment are divisible into three basic categories:-

(1) Waste, which are hazardous and must be treated suitably before throwing them as waste.

(2) Waste, which are not hazardous, and recovery, recycling and reuse of valuables in it could be Done economically.

(3) Waste which are not hazardous and have little / no value added perspective.

In many cases, these solid waste contain valuable materials, which can be recovered and recycled in the process. Recycling and utilization of these solid wastes through an integrated waste management approach havegained special significance due to several factors such as economic advantages, augmentation of primary resources, better and cleaner environment, conservation of energy & water and compliance with the law. [Ghosh and Sinha, 1990].

Management of waste creates values ethical and aesthetic in nature. It is beneficial from pollution control point of view and even generates revenue. Benificiation and recycling of waste products can cater to the needs of the consumer sector. In this competitive industrial age, the aspect of waste control is of paramount importance.

The above mentioned goal can be achieved in two ways:

(a)By reducing the quantity of waste generates.

(b)By recycling and reutilizing the generated waste in different processes for value addition.

Any waste minimization programme should first attempt at classifying the waste in manufacturing process. A simpler way is to classify them either as ''intrinsic or extrinsic waste''. Intrinsic wastes are those which are inherent in the fundamental process configuration i.e. product and process design itself. These represent impurity in- products, by-products, co-products, residues and spent material of the process configuration. Extrinsic wastes are more functional in nature and are not necessarily inherent to a specific process or product configuration. These may occur as a result of unit upsets, fugitive leak, process shut downs or material handling practices etc.

The reduction of intrinsic waste requires modification of the process system often significantly at high cost. Such changes tend to require much research and development evaluation, major modification to the process and time. On the contrary the reduction of extrinsic waste can often be done readily through administrative control i.e. improved operational / maintainance procedure, improve layout, operator training, changes in auxiliary aspects of the process etc. Thus reduction of intrinsic waste is ''Technology oriented'' where as reduction of extrinsic waste is ''Management oriented''.

Thus a proper classification of ''Waste'' would help in identifying a cost-effective solution for its minimization. One of the major concerns of waste-management is the widely varying quality of waste, this makes it very difficult to tailor it for any down stream usage.

In key steel manufacturing areas, the unresolved waste problems are identified and suggestions provided with respect to zero waste alternatives. A methodology is given for implementation including economic incentives for reducing waste in all aspects of the steel plant.

The process of waste minimization, i.e.; "Zero Waste" is that it should be a structural approach to minimizing energy consumption, air emission, toxic and non toxic waste generation either directly or indirectly by a manufacturing process (Mukharjee and Chakraborty, 1999). The zero waste concepts are now being adopted in many ferrous and non-ferrous and mineral industries in North America.

It acknowledges that the reduction, recycling and recovery of waste discharged by a production process is good for a business bottom line as well as the surrounding community's well being.

1.5 Statement of the problem

Management of solid waste is a challenge for efficient and cost-effective operation at Bhilai Steel Plant because the actual of waste generation is more than any other plants in India and abroad as well. Considering an average of last three years (2004-2007), this plant has generated about 2.77 million tones of solid waste for an average production level of 4.0 million tones of crude steel. Out of the total waste generation of 2.77 million tones, 0.68 million tones(24.8%) was sold, 0.41 million tones was recycled (14%) and rest 1.67 million tones (60%) was dumped in dump yards. There are 30 different solid waste materials (Table 1.1) generated in the plant.The major solid waste in the form of slag (Blast Furnace Slag, Steel Melting Slag), Dusts (Flue Dust, SMS Dust), Sludge (GCP Sludge from Gas Cleaning plant of Blast Furnace, Acetylene Sludge from Acetylene Plant, Neutralization Plant Sludge and Palm Oil Sludge from Cold Rolling Mill, Acid Treatment Plant Sludge from Sillcon Steel Mill), Scale (Mill Scale from Hot Strip Mill) and Ash (Fly-Ash & Bottom ash from thermal power plant) etc. but the present study includes only the Flue-Dust, Fly-Ash and LD-Slag. In terms of quantity, waste from iron making (74.34%) and steel making (14.84%) and captive power plant (1.30%) are the three important solid waste constituting about 90.48% of total generation as shown in FigII.1.

The quantittative status of source wise major solid waste generated, sold, recycled and dumped in Bhilai Steel plant , considering an average of last three years(2004-2007) is shown in Table 1.4 and Fig. II.2. The data shows that the total generation of solid waste is abnormally high, the percentage of recycling/ reuse is very low and percentage of dumping is very high.

Collection, transportation and dumping of waste are very expensive and a large area of land is needed.Bhilai Steel Plant is facing space constraints due to filling up of old dump yards and limited site area available for opening of new dumping space. Moreover, high cost of dumping due to longer lead distance for future sites adds to this predicament.

At present, there is no system for monitoring the quality of surface run off and underground water in the dumpsites. Therefore, possible impact of the dumps on water pollution is not fully understood.Detailed data on cost of handling and dumping the solid waste could not be ascertained. However, for some of the materials, the disposal cost is about 90/T. On this basis, the cost of dumping of an average of 0.68 million tones of waste during million tones of waste during last three years might have been as high as Rs. 8 Crores. No data is available on the large amount of solid waste already dumped in various dump yards during the last 45 years. Available area and volume inside the existing dump yards and estimated capacity of future dump-site are also not fully known. It is felt that lack of well-defined organizational structure (considering solid waste management as an independent function), and adequate data base for decision-making are by far the most important factors for proper solid waste management in Bhilai Steel Plant.

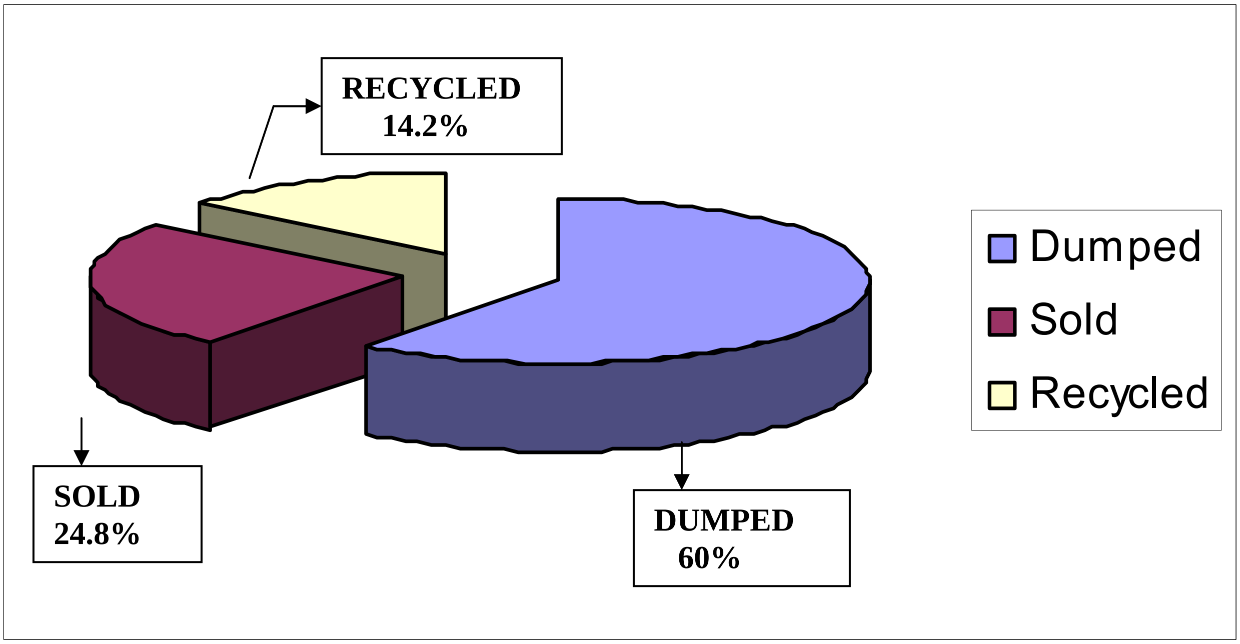
Reduction in generation of waste and gainful utilization and recycling of these wastes not onlyimprove the economics of operation but also prevent degradation of the ambient environment. It is therefore essential to study all these waste prior to their processing for converting them to value added wealth in one form or other.

In this proposed work, characterization of solid waste of BSP is beyond the scope and as such the waste related to metallurgical industries, thermal power plant have only been characterized in respect of physical, mineralogical and chemical (major, minor and trace elements) properties.

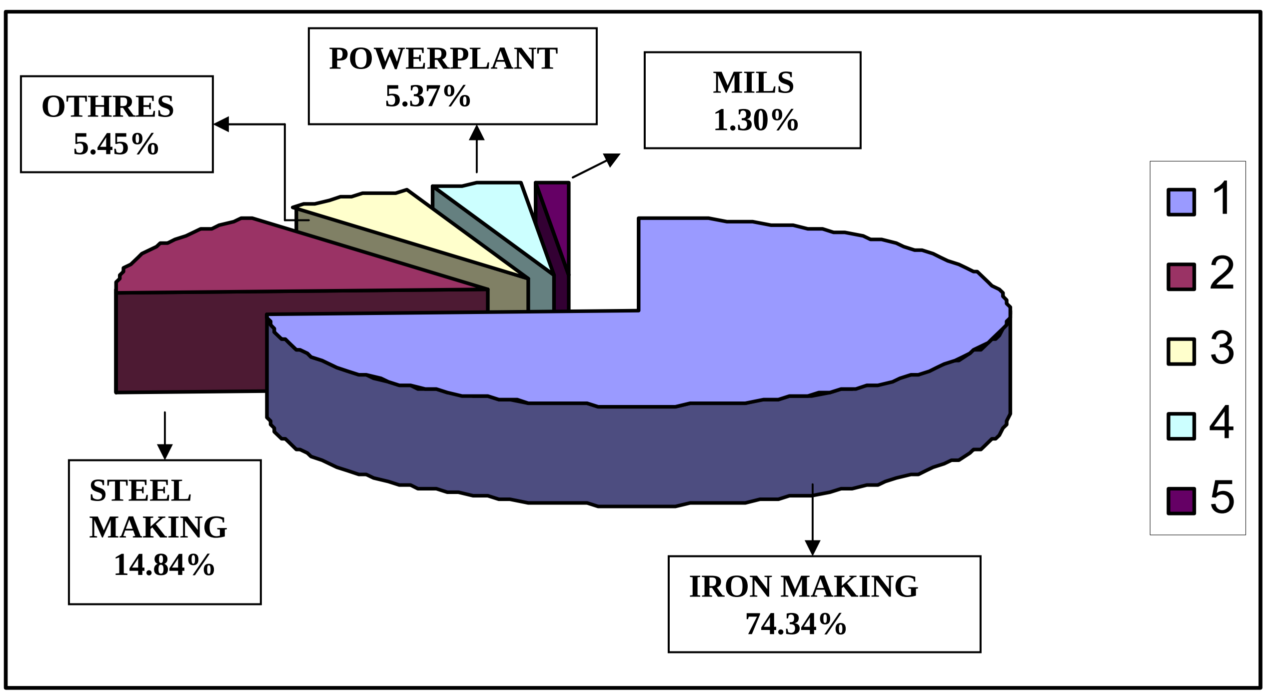
Table 1.4: Quantitative status of major solid waste at BSP

Unit	Name of solid waste	Generation (T)	Sale (T)	Dumped (T)	Recycled (T)
Iron Making	1.BF slag 2.Flu dust	1954383 109049	321466 54261	1632917 21647	0 33141
Steel Making	1.BOF slag 2.THF slag 3.LD dust	238090 149823 24186	96896 149823 11722	- - -	141192 0 12464
Captive power plant	1.Fly ash & Bottom ash	36322	34242	-	2080
Hot Strip Mill	1.Mill scale	113119	0	2374	110745
Others	1.Lime fines 2.Watse refractories 3.Other solid Waste	86164 25226 38940	0 2112 18249	0 10535 4884	86164 12579 15807
Total		2775302	688773	1672357	414172
Percentage		**100**	**24.8%**	**60%**	**14.2%**

Source: Environmental Engineering Department, Bhilai Steel Plant



FigII.1**: Pi-Chart showing the major solid waste status of BSP in the year 2004-07**.



FigII.2**: Pi-chart showing different wastes generated form BSP in the year 2004-07**

On the basis of characterization results, preliminary investigation on recovery of valuables from selective waste like Flu Dust & Fly Ash has been undertaken by various physical beneficiation techniques. Limited attempts have been made to find out different means of further utilization of few of these waste generated from Bhilai Steel Plant.

1.6 Scope of present Investigation

The present study is both basic and applied in nature. In an integrated steel plant like Bhilai Steel Plant (BSP), a number of manufacturing processes are employed using different types of raw material and processed material. It is but natural that waste are generated from its different units like Coke Making & coal chemicals, sinter Making, Iron Making, Steel Making, Rolling Mills, power plants etc. Other waste are from the various pollution control equipments like electrostatic precipitators, Bag filters, Scrubbers, Wastewater treatment plants etc. However, in this research programme, investigations are limited to a few types of waste being generated from some important units. The scope includes physical, mineralogical and geo-chemical characterization of the waste materials generated at Bhilai Steel Plant, Chattisgarh.

The investigation is also designed to find out the possible ways of the processing some of these waste materials for their optimum utilization.

With these objectives, the work plan under this research programme has been structured into two parts, such as characterization and utilization of the solid waste generated at BSP. Before discussing the characteristics of different wastes, their process technology and origin are briefly described.

(A) Characterization

- Mineralogical and geo-chemical characterization of waste material generated from metallurgical furnaces (Iron Making & Steel Making).
- Mineralogical and geo-chemical characterization of waste material generated from thermal power plant.

(B) Utilization

The results of the above investigation have been synthesized to find out the amenability of the waste materials to upgrade and further utilization.

Chapter-II

REVIEW OF LITERATURE

Review of literature

As the characterization and management of solid waste of any integrated iron and steel industry the world over constitute a burgeoning arena that steps into the frontier of R & D about one and half a decade back, the quantum of research in this work has been far off being voluminous. In India, it is still in infant stage. Further, the spectrum of solid waste generated by iron and steel plants is quite large & diversified but the R & D work pertaining to them is not equipoise. In the fields of few waste products like metallurgical slag, dust/sludge, considerable research work has been done while some other waste like acetylene sludge and palm oil sludge have received scant to no attention in the field of R& D. More over a large bulk of literature on waste is available inform of seminar/synopsis/workshop proceedings which have limited circulation. As such it would be an uphill task to peep back into the historical aspect of its scientific research development against the backdrop of the present state of the art. Yet a modest attempt is made here to review the available scientific literature. Besides the following core literature reviewed, some pertinent references are cited in various chapters dealing with different types of waste.

A large number of literature are available on total management of waste generated from a Steel plant focusing on different aspects of pollution measures, safe disposal and recirculation etc.Major noteworthy contributions on overall waste management are by Leonard (1997), Padhi et al. (1999), Chatterjee (1993), Rechner (1995), Basu (1997), Mukharjee and Chakrabarty (1999) etc.

Blast furnace flu dust is usually found to be contaminated with Zn and lead or contain alkali elements that make them unsuitable for reuse. However, recovery of Zn and Pb values from BF Flu Dust has been successfully attempted by Piret and Muller (1991), Stamatovic and Themelis (1993), Imris(1995), Lehner et al. (1995). Erol and Sevinve (1995) studied the effect of alkalies on operation of blast furnace. Murthy & Gangopadhyay (1999) discussed the utilization of slag, the granulated slag from Bhilai Steel Plant, India in particular for the production of slag cement.

As regards the metallurgical slag, reports are available on utilization of BF Slag while slag from steel melting shop is not fully discussed because of inherent problems. Kreulitsch and Krieger (1992) showed that LD process is suitable for recycling steel waste to produce a high-tech steel product and it is ecologically superior over some other steel melting processes. Kim et al. (1998) has studied the physico-chemical characteristics of LD slag. The major phases that are being found in LD slag includes Dicalcium ferrite Calcium aluminate and Wustite.Steel slag also contain some reactive mineral phases such as $2CaO.SiO_2$, $3CaO.SiO_2$ and free CaO and MgO (Goldrig and Jukes, 1997). Das et al (2000) worked on the recycling of steel plant waste through sinter plant.

Sinha et al (1999) summarized the work done at various steel plants of the country in the area of utilization of waste which includes use of LD slag as soil conditioner, recycling of LD slag through sinter routes, manufacture of fly-ash bricks & light weight aggregates, agglomeration& recycling of lime fines. Technology for the treatment of steel plant dusts is also described by Braeza et al. (1991).

A volume of literature is available on study of Fly-Ash generated from a thermal plant. Tripathy and Sahu (1995), Sahu (1999) detailed the characteristics of ash in general. Kumar & Sharma (1999) discussed the strategies to tackle the fly-Ash problems against the backdrop of present state of generation. Jha et al. (1999) discussed the utilization of fly-ash in agricultural sector.

Dykstra et al. (2000) attempted high resolution micropetrographic study of coarse-grained agglomerated MSN fly-ash. Hoffman (1998) discussed the use of fly-ash in Western United States. Kirk and Davis (1999) have determined the usefulness of fly-ash to control bacterial growth in diary bedding. Vimal et al (1999) constructed the potential of returns in dollars following various utilization avenues of Indian fly-ashs:- like fly-ash cement, fly-ash based wood substitute, fly-ash based tiles,paints &enamels, reclamation of low lying areas, in the construction of road and fly over, embankments and so on. Nayak et al (1999) reported the preparation of fly-ash bricks, aggregates etc. However, characterization of fly-ash generated from BSP is not available in the literature.

The processing of metallurgical waste and recovery of metal values has been reported by several researchers. Schriefer (1997) focused attention to reaping the value from dust & slag. Grebe and Lehmkuhler (1991) discussed the recycling of residues with high Fe content & low Zn and Pb contents. The process permits utilization of carbon content from the waste as a reductant. Study carried by Reddy et al (1996) indicated the probability of recovery of 60% carbon values from flu dust through conventional flotation technique. Parrat and Aumonier (1996) explained the techniques used for upgrading metal extraction from slag.

In may be summarized from the review of some of the important literature that basic characterization study of all types of waste generated from Bhilai Steel Plant has been either reported to a limited extent or not attended at all and hence this present investigation work has been taken up.

Chapter-III

METHODS &MATERIAL DETAILS

3. MATERIALS AND METHODS

3.1Material Details

The study of solid waste of BSP is the main focus of this research pursuit. These waste-rejects were collected at different points keeping in mind their residence time, which was tentative and on theoretical basis. The different plant rejects include: (A) waste from Metallurgical Furnaces, i) Flu Dust ii) Steel making-LD Slag. (B) Waste from Thermal power plant-Fly-Ash& Bottom-Ash. These samples have been characterized in respect of their physical, mineralogical and chemical properties and aspects of possible recovery of any value-added products from some of them have been attempted.

3.2 Methodology

3.2.1 Mineralogical Analysis

Mineralogy of solid waste generated through different process routes has been established by synthesizing the integrated results brought out by the following instrumental methods:

Optical Microscopy

The polished surface of various types of waste materials was prepared using araldite in a mould to study under reflected light microscope. These samples were polished by conventional polishing techniques, cleaned ultrasonically and examined under Orthoplan Microscope (Leitz make). The mineralogy, texture, microstructure and inclusions etc. in respect of various waste were studied by this method.

Electron Microscopy

Unlike optical microscopy where light is the source for image formation, in electron microscopy, the image formation is due to the scattering of electron beam scans over the sample. In general this study: i) brings out the size, shape and micro morphology of minerals and ii) their textural patterns.

For SEM study, powdered sample was first coated with ultra thin film of gold by an ion sputter JFC-1100 and then was exposed under a Japanese make electron microscope (JEOL, JSM-35CF) for study under high resolution. For this purpose the working height was kept 15mm with voltage ranging between 10Kv with beam current 100nA.By this technique, EDS spectra of individual sample showing the semi-quantitative abundance of major and minor elements was brought out.

X-ray Diffraction

X-ray diffraction technique (XRD) was extensively used for identification of various mineral phases and assessing the relative abundance of them in a sample. The XRD was carried out by means of Phillips Diffractometer (PW-1710) having automatic divergence slit, receiving slit and graphic monochromator assembly. Cu Kα radiation operating at 40 Kv and 20nA was used for this purpose. A diffraction pattern recording the angle 2θ against the intensity was obtained over a range between 6 degree to 7 degree corresponding to its d-values between 10A and 1.34A.The scanning rate was 2 degree per minute with recorder full scale set into 2*10 counts. Each mineral phase exhibits characteristic reflection peaks corresponding to its d-values. These sets of d-values were matched with JCPDS data book (1980) and various minerals were identified. Further the variations in the peak intensities of different mineral phases in the sample indicate their relative abundance.

3.2.2 Chemical Analysis

The objective of chemical analysis was to determine the chemical composition of the waste materials by different established techniques and distinguish the characteristics of one waste from the other by chemical means.

The major, minor and trace constituents in different wastes were taken up by wet chemical methods and using different instrumental techniques such as XRF and ICP-MS. Chemical analysis of different mineral phases in the solid state was determined using electron probe microanalysis (EPMA) technique.

X-ray Fluorescence

Major and minor constituents of various slag samples were analysed by XRF spectrometry on Phillips (PW-1400) X-ray spectrometer with Scandium and Rhodium targets using pentaerythritol (Al, Si), Thallium Acid Pathalate (Na, Mg), Germanium (P) and Lithium Fluoride (for heavier elements) as analyzing crystals in vacuum medium. International and in-house standards of appropriate compositions were used for calibration. Both major and minor elements were determined by pressed powered pellet technique.

Atomic Absorption Spectroscopy

Analysis of trace constituents like Cu, Ni, Co, Pb, Zn etc. were made with a Varian-Tectron (AA-1475) ABD atomic absorption spectrophotometer fitted with an air acetylene burner. A shielded hollow cathode lamp served as the source of light for the elements to be determined. The absorption measurements were recorded.

Electron Microprobe

The chemical composition of different phases in micron areas was determined by means of Electron Microprobe. The ARL-SEMQ-II (take-off angle of 52.5 degrees) electron microprobe in the Geochemists Institute, Universitat Gottingen, Germany; which is equipped with six spectrometers and four different crystals (LiF, PET, ADP, TAP), operated at 15kV accelerating voltage and 15nA sample current was used for this purpose. The matrix corrections of the intensity measurements were made using the ZAF correction programme by Bence and Albee (1968). Electron probe micro analysis (EPMA) of typical slag and dust from metallurgical furnaces were carried out.

3.2.3 Beneficiation Study

Flotation: To recover carbon particles, simple flotation techniques are employed. Denver D12 sub-aeration flotation machines with 10 liter capacity cell were used in the flotation studies. The impeller speed was maintained at 1500rpm in all the experiments. For flotation studies, around 800gms of sample was mixed with 3200ml of water and conditioned for five minutes in presence of depressant(Sodium silicate) and again for five minutes in presence of collector. The slurry was further diluted to 10% solid by mixing additional amount of 400ml of water. The frother was added and further conditioned for one minute. Then air was introduced and flotation was carried out for a period of three minutes. Both concentrates and tailings are collected, dried, weighed and analysed for carbon.

Tabling: The tailings fro flotation technique and non-ferrous phases present in dusts were separately treated on a laboratory model table (1016X457mm Denever Wilfley Table). The Tabling works on the principle of gravity separation technique.

High Intensity Magnetic Separation: Both dry and wet magnetic separation study was undertaken for selective sample to recover the iron values.

Representative dust sample was subjected to magnetic separation on BOX MAG dry high intensity magnetic separator at 25,000 Gauss. Valuables from metallurgical furnaces were recovered by this process.

Chapter-IV

WASTE FROM METALLURGICAL FURNACES

WASTE FROM METALLURGICAL FURNACES

This chapter pertains to the waste generated from metallurgical furnaces that process raw materials to pig iron and steel include iron making furnaces (Blast furnaces) & steel making shops/furnaces (SMS-I & SMS-II). The crude steel is then processed through different mills to produce salable steel (Fig.III.1). During the production of hot metal, two broad types of waste such as slag and sludge/dusts are generated . Before characterizing the waste generated from individual furnaces, a brief description of the process technology and generation process of waste is given.

4A. Iron making Furnace (Blast Furnace)

In BSP, for production of hot metal(pig iron) three broad raw materials such as iron ore, limestone and coal are smelted in blast furnace. During smelting iron ore i.e. hematite (Fe_2O_3) gets reduced to Fe-metal and all impurities come out in form of slag.

Process Technology

Blast Furnace is basically a counter current apparatus, composed of two truncated cones placed base to base having parts such as Throat, Shaft(Stack), Belly(Cylindrical shape), Bosh and Hearth.

In Bhilai Steel Plant, there are seven furnaces. The annual revised (after modernization) rated capacity of hot metal is 5.3 M.T with only five blast furnaces in operation. Raw materials from different bunkers are conveyed by belts to the Skip car. Screened iron ore is made available from the Blending plant. The raw materials from Skips are dumped in a receiving Hopper at the furnace top. With the help of modern Bell less top system the material is distributed at various positioned inside the furnace as selected by the operator. The furnaces are kept level, with stock level of 1.5 to 2m. The raw materials used in the Blast Furnaces are Iron ore, Sinter, Coke, Limestone, Manganese ore, Quartzite and scrap metal. Apart from these sold raw materials, it also needs air for supplying oxygen required for the combustion of coke and water to keep the various elements of the furnace cool.

The entire furnace is lined with suitable refractory and in addition to refractory line, there are water coolers, designed to enhance the life of the furnaces. Blast furnace is a vertical shaft furnace, enclosed in a welded shell, lined with fire-clay bricks of high alumina content. The hearth bottom, bosh and the cylindrical part of the bosh are cooled by means of plate coolers. In the shaft, there are cantilever coolers. The walls of the furnace top aer protected by steel refectory lined plates. In the hearth, there is a tap hole of suitable dimension and length for the purpose of tapping the hot metal. Bulk raw materials like Iron ore, Limestone, Sinter will form the "O" part of the charge and coke forms the "C" part. Once these materials are charged into the furnace top, they go through numerous chemical & physical reactions while descending to the bottom of the furnace. The iron ore, pellets and sinter are reduced. This simply means that the oxygen in the iron oxides is removed by a series of chemical reactions. The different reactions take place in different zones inside the furnace is as follows:

Upper Stack zone

*****Reduction of oxides

$3Fe_2O_3 + CO_2=2Fe_3O_4+ CO_2$ at 850˚F

$Fe_3O_4+ CO=3FeO+CO_2$ at 1100˚F

$FeO+ CO=Fe+CO_2$

*Decomposition of hydrates

$CO+H_2O=CO_2+H_2$

* Deposition of carbon.

* Decomposition of carbonates.

Middle Stack zone

* Direct/ indirect reduction.

$FeO+CO=Fe+CO_2$

Since the reaction takes in the presence of excess carbon at a high temperature, the CO2 is reduced to carbon monoxide.

$CO_2+C=2CO$

$FeO+C=Fe+CO$ at 1300˚F

- FeO is Iron oxide throughout this region.

Lower Stack zone

***** Calcination of Limestone.

* Reduction of unreduced Iron.

* Formation of slag, final reduction of FeO & melting of Fe.

Combustion zone

* Burning & combustion of coke.
* Coke and hydrocarbons are oxidized.

Hearth

* Saturation of carbon with Iron.
* Reaction impurities reach their final concentration.

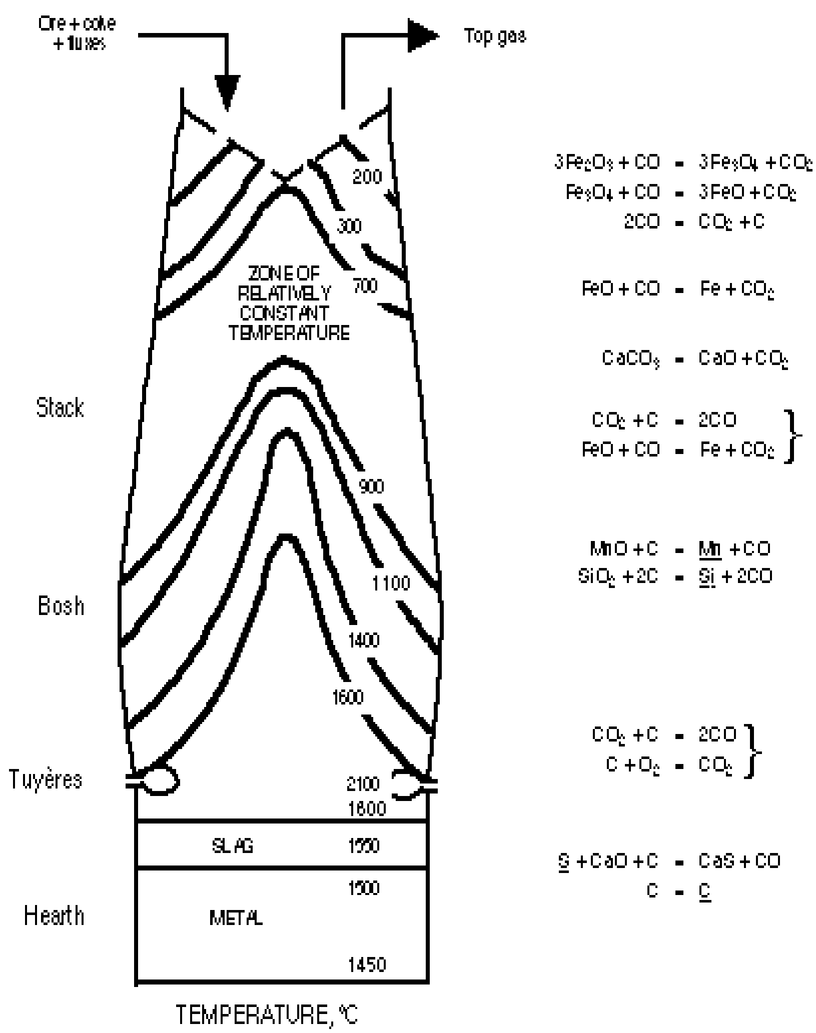


Fig.IV**.2 Different zones of Blast Furnace**

The CaO formed due to the decomposition of limestone is used to remove sulphur from the Iron, which is necessary before the hot metal becomes steel. This sulphur removing reaction is as follows

$$FeS+CaO+C=CaS+FeO+CO\uparrow$$

The comprehensive picture of input & output flow sheet is shown in Fig III.2. As metallurgical coal used at BSP is high in ash content and Iron ores contribute high alumina, slag volume in Blast furnace is high resulting in lower productivity of the blast furnace. Therefore, to increase productivity and the quality of hot metal, the coke rate needs to be reduced. For this, production of high flux sinters with MgO is made. At BSP, there are two sinter plants. Sintering is the process of agglomeration of iron ore fines, dolomite, limestone from the fuel contained in the charge. The lumpy porous mass thus available is called sinter.

4A.1. Waste from Blast Furnace

The reduction of iron oxide in Blast Furnace (BF) involves the evolution of number of wastes. These are blast furnace slag, flue dust/ sludge and gas cleaning sludge (Fig III). The input and output figures of Blast Furnace for production of one tonne of hot metal are given in Table 3.1.

Table 4.1: Input & output data of Blast Furnace for production of 1Tone of Hot Metal

Input		Output	
Iron ore	985kgs	Hot Metal	1000kgs
Sinter	800kgs	Slag	435kgs
Mn-ore	35kgs	Flue Dust	25kgs
Limestone	08kgs	BF Gas	1830kg
Converter slag	32kgs		
Coke	596kgs		
Compressed air	25M3		
Electricity	33.7kwh		
Air blast	2600M3		
Water	40M3		
Steam	120kgs		

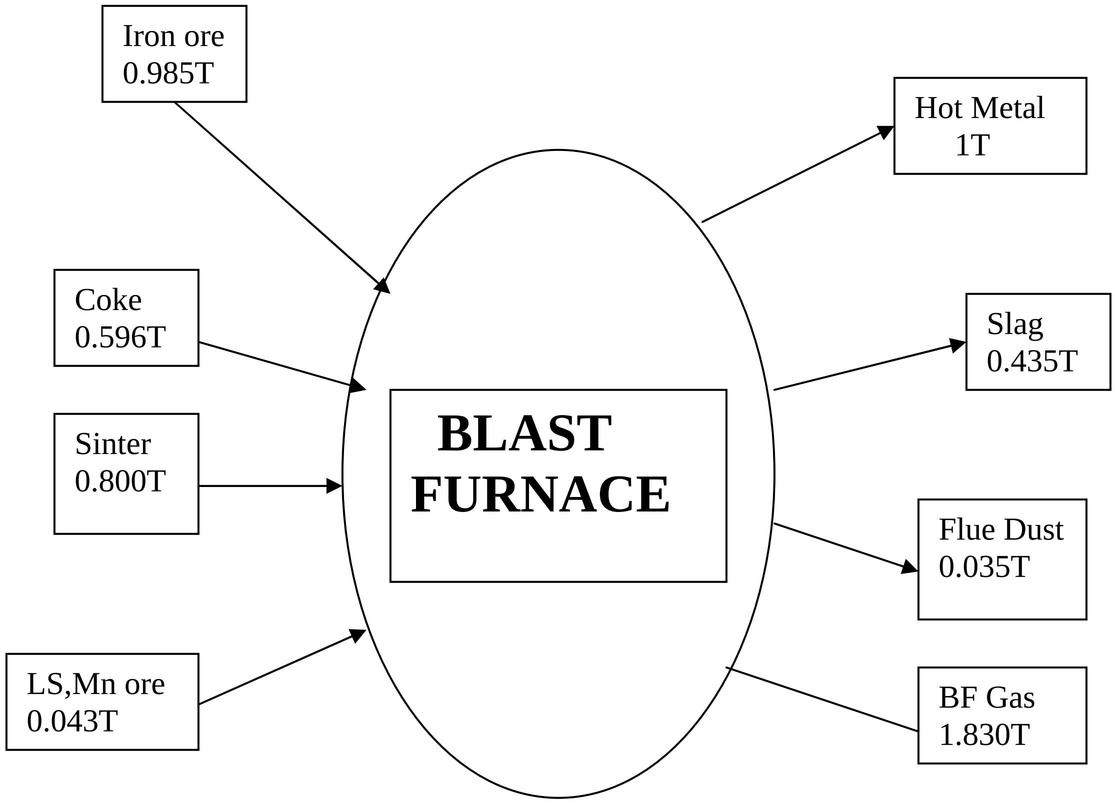


Fig.IV.4**: Schematic diagram showing input-output of Blast Furnace**

4A.1.1 BF Dust (Flue Dust)

4A.1.1.1 Generation Process of Flue Dust

In addition to Hot Metal and slag, one more gaseous product gets out from the top of the furnace known as Flue Dust. This gas is finely charged with dust particles. Some of these particles are directly separated by a dust catcher or collected through precipitator as sludge (Fig III.3).

4A.1.1.2 Characteristics of Flue Dust

Physical Characteristics

Blast furnace dust or flue dust is fine-grained and black in colour that soils hand. The black look of the flue dust is due to the presence of large volume of unburnt coke particles. They are mostly irregular in shape though a few euhedral grains are uncommon. The grain density of flue dust sample (2.78). Size analysis of fly-ash is given below in Table 4.2.

Table 4.2: Size analysis of flue dust

Size in micron	Wt in gms	Wt%	Cumulative
500	24	3.11	3.11
250	360	46.75	49.86
150	242	31.42	81.28
75	88	11.45	92.73
<75	56	7.27	100

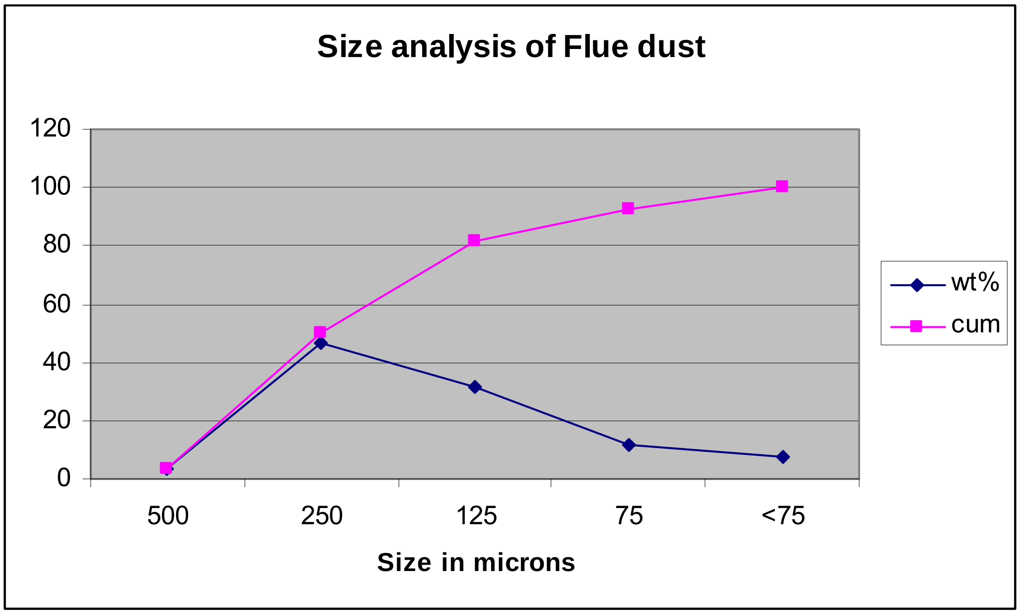


Fig. IV.5 Size analysis graph of Flue dust

The size analysis graph shows that the heavier fraction constitutes around 90% of the total.

Mineralogical characteristics

Dusts largely consists of sinter particles (around 40%), coke fragements (around 30%), metallic prills (around 20%) and unreacted original feed particles (around 10%). The different phases identified in order of abundance, from their X-ray diffraction pattern (Fig.IV.6) includes Hematite, Quartz, Magnetite and Wustite. Reflected and SEM studies as described below, have brought out the characteristics of the following various mineralogical phases.

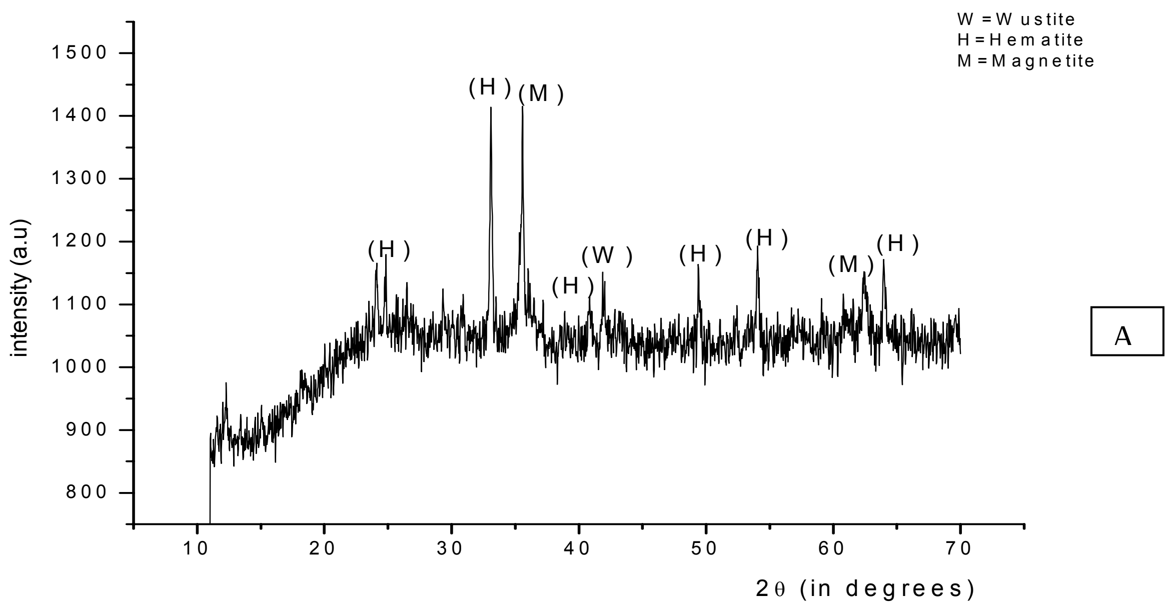
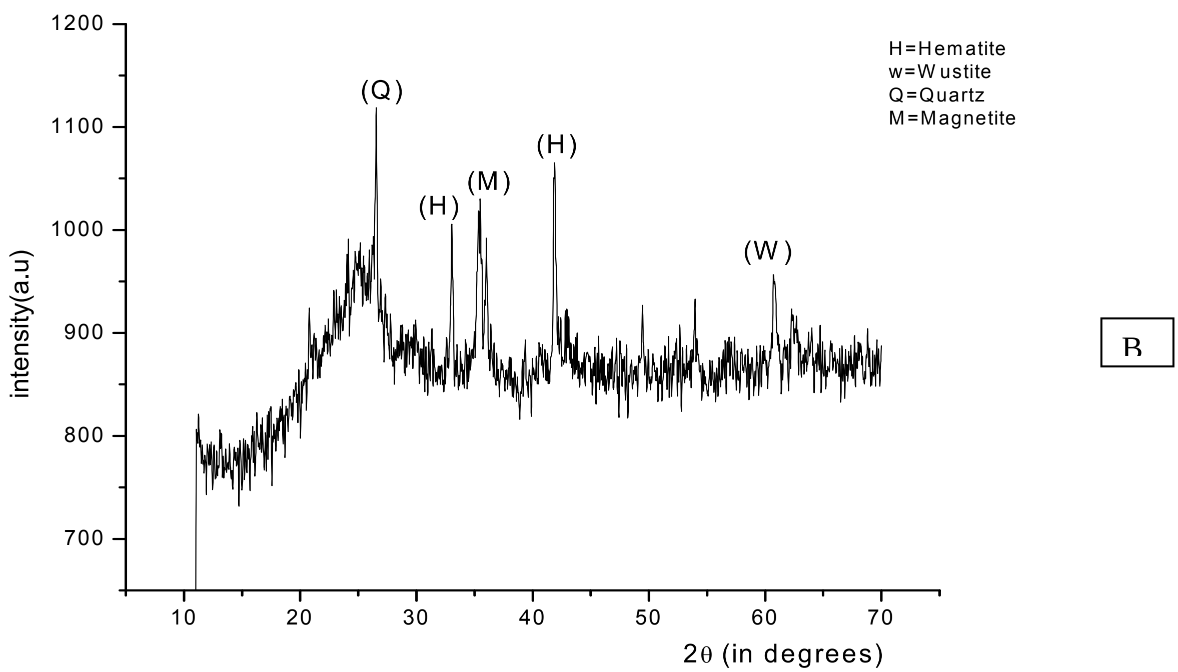


Fig IV.6: **XRD analysis of Flue dust**



Optical Micrographs of Flue dust

1. **Feed grains, partly reacted**:-

A large amount of dust particles are either unreacted or Partially reacted ore-oxide particles (Fig. IV.7A). some of them show spherical crust developed during its exposure to high temperature. These have different shapes (angular, irregular) and occur in varying sizes. (Fig. IV.7B).

2. **Coke particles**: -

Coke is fed to the blast furnace as a fuel. Many unreacted coke particles get released into air during smelting operation. Abundance of such particles gives a black colour to BF dust. It is readily recognized under microscope by its characteristic colour, low reflectance, anisotropism, high porosity and cellular structure (Fig. IV.7C). The average size of the coke particles is larger than other phases. Therefore, the carbon values are concentrated largely in the coarser fraction.

3. **Newly formed grains**:-

Amongst the dust particles, some are partly transformed and a few well-developed newly formed secondary crystals are present. The figure IV.7B illustrates better development of magnetite grains with isolated hematite grain. Transformation of magnetite to wustite is observed in Fig IV.7F.

4. **Sinter particles: -**

These are mostly composed of irregular wustite crystals (Fig IV.7F). A single grain sometimes shows magnetite followed by wustite occupying the intergranular spaces. Occasionally, sintered wustite grains show metallization at their grain boundary region. The presence of wustite and iron metals attest to the dust generation till metallization.

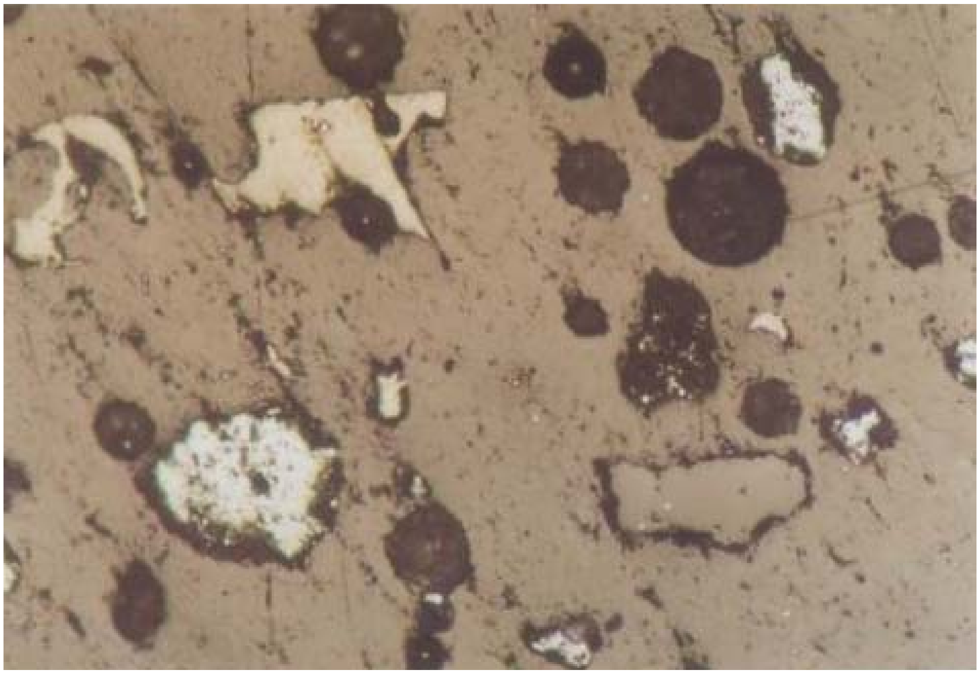


Fig IV.7A: **White grains of Hematite. The pink ones are of unburnt coke. The grey elongated homogenous greenish is of some kind of flux. X 100**

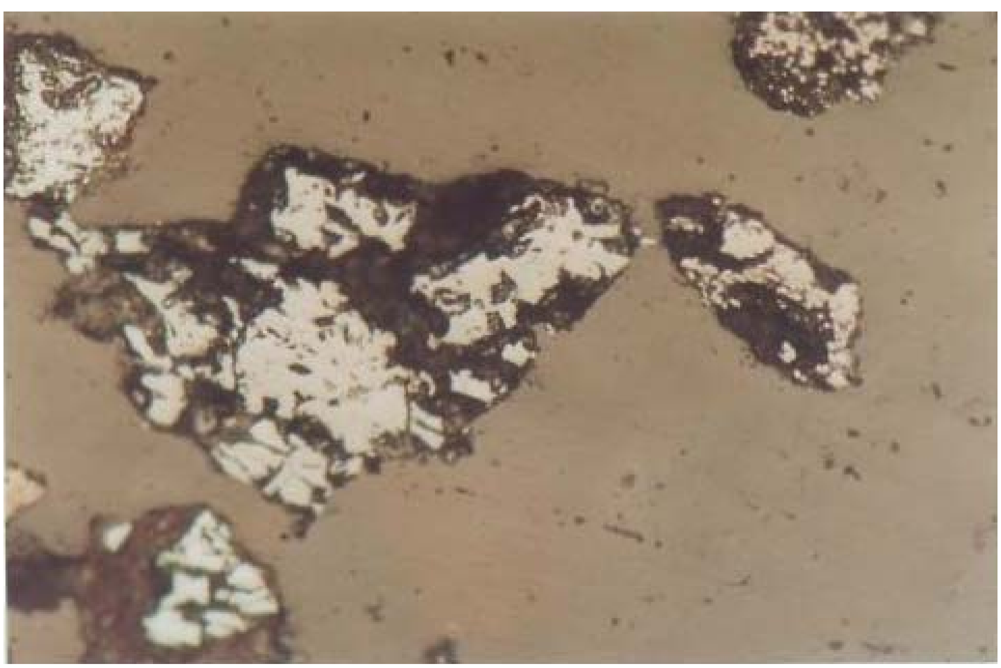


Fig IV.7B: **Magnetite with unaffected Hematite grain. X 200.**

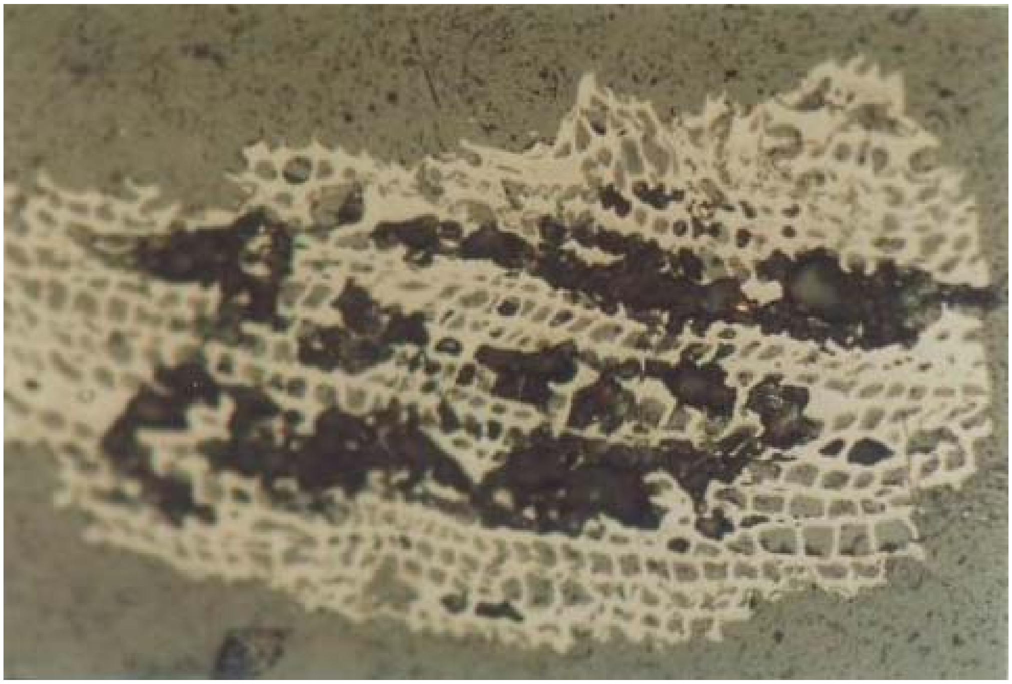


Fig IV.7C: **An unburnt coke grain showing leafy structure. X 200**

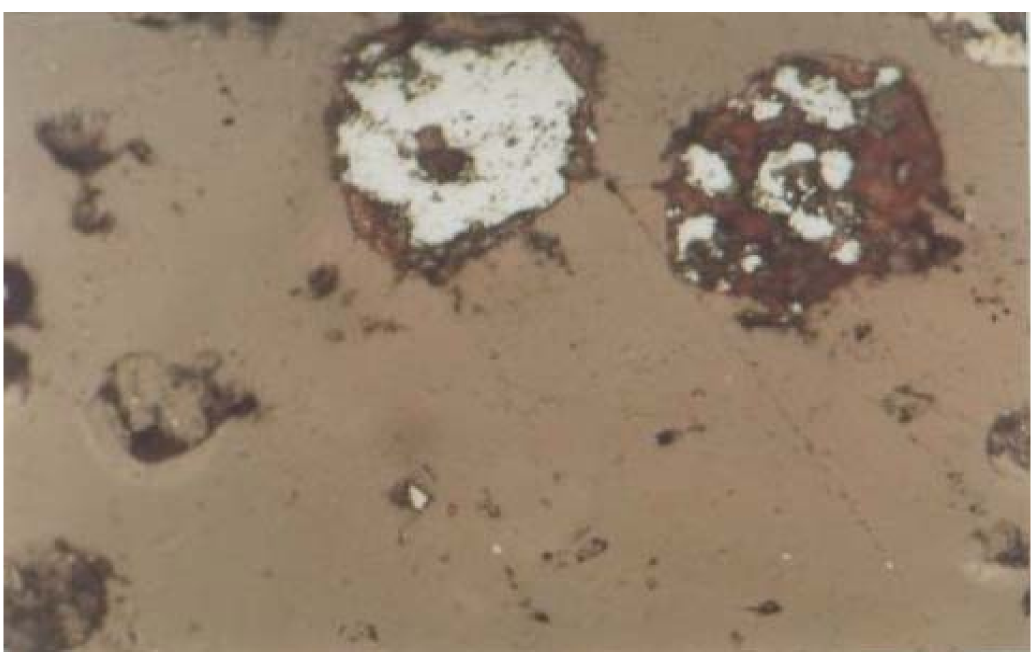


Fig IV.7D: **Unaffected Hematite grain with limonite incrustation. X 200**.

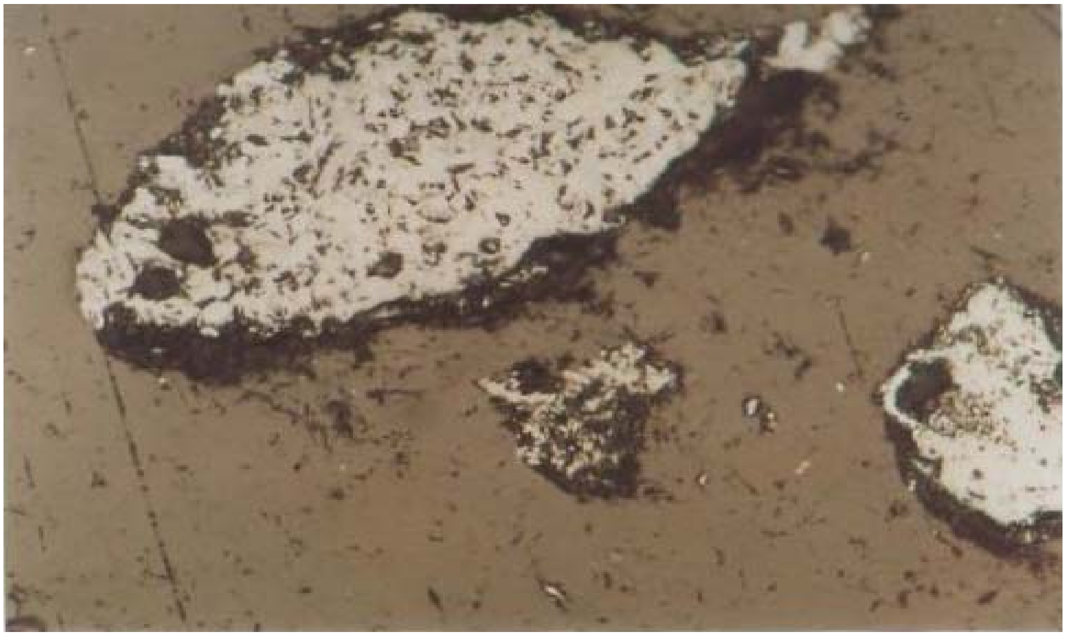


Fig IV.7E: **One lenticular grain of Magnetite (top) & two other grains of unaffected Hematite X 200**.

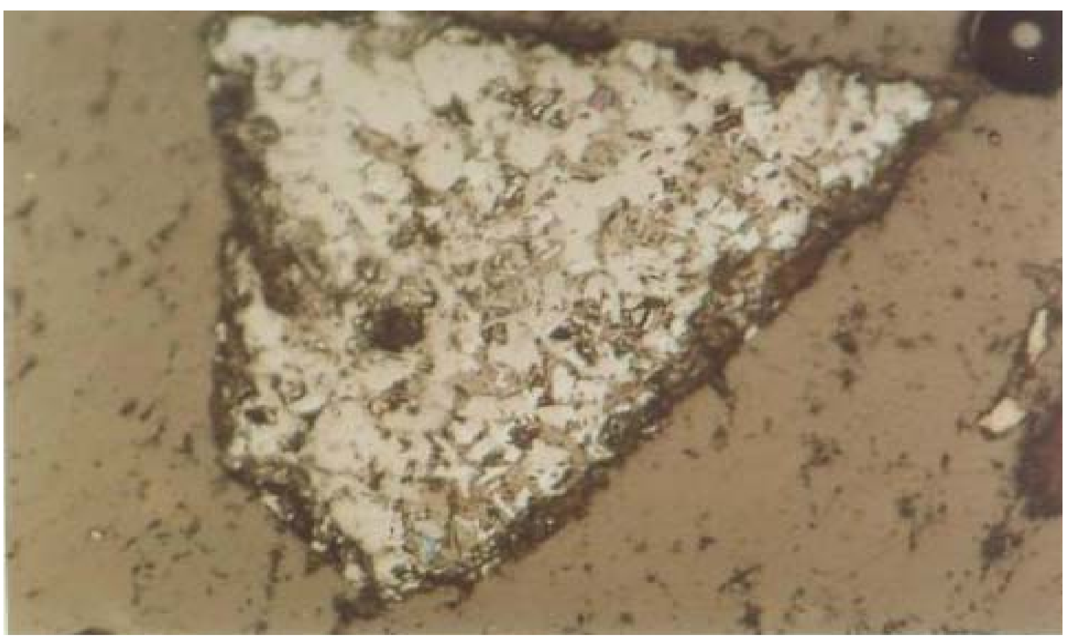


Fig IV.7F: **A large agglomerated grain showing fine grains of Magnetite with Wustite occupying the intergranular spaces. X 200**

Chemical characteristics

The major, minor and trace element distribution in the flue dust sample is shown in Table 4.3. This is rich in carbon (31.0% fixed carbon), Iron (Fe_2O_3- 42.6%) and moderately rich in silica (SiO_2-5.7%) alumina (Al_2O_3-10.40%) and calcium (CaO-2.00%). Its fixed carbon content decreases with size (+250micron-31%, +150micron-24%, +75micron-8.5%, <75micron-4.5%). Environmental hazardous elements like Pb, Zn, Cu, Cr, Mn, Ni, Th, U are well under permissible limits. The harmful component in many plants as reported in literature comes from recycled scrap input in the blast furnace.

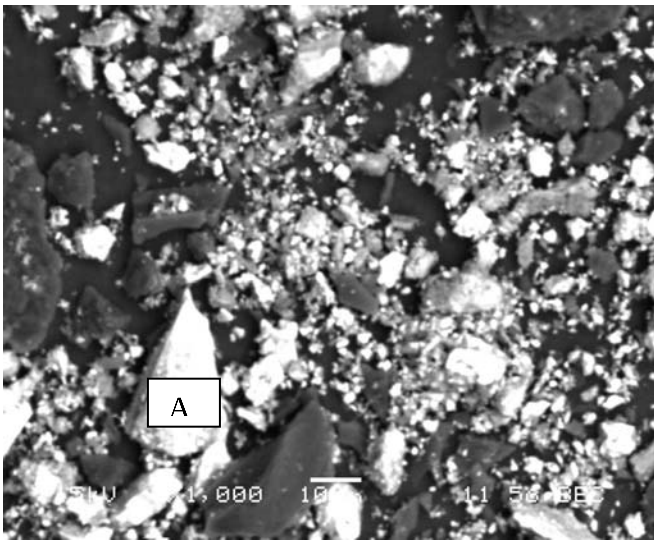
Recycling of flue dust in BSP is being done because it contains low level of alkali (Na+ K< 1.70%). Alkaline elements accumulate in the blast furnace and corrode the refractory lining.

Table 4.3: Major, Minor & Trace element Distribution pattern in BF dust.

Major Elements	**Wt%**
Carbon	4. 31
Fe_2O_3	42.6
SiO2	5.7
Al_2O_3	10.40
CaO	2.00
MgO	1.6
MnO	0.57
Trace Elements	**(in ppm)**
Pb	25.12
Zn	42.52
Cu	29.60
Cr	0.50
Ni	18.22
Th	43

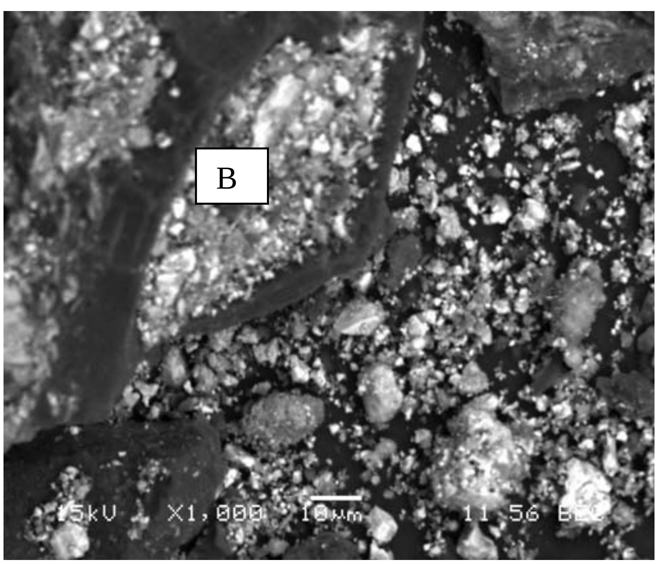
SEM Analysis of Flue dust

Unlike optical microscopy where light is the source for image formation, in electron microscopy, the image formation is due to the scattering of electron beam scans over the sample. In general this study: i) brings out the size, shape and micro morphology of minerals and ii) their textural patterns. The SEM analysis of flue dust is given in Fig IV.8(A-E)



Element	Wt%
Fe	48.41
C	43.16
Al	2.30
Si	1.39

Fig IV.8A: **Iron carbide crystal in flue dust**



Element	Wt%
Fe	56.09
C	38.80
Ca	3.43

Fig IV.8B: **A grain of iron carbide containing small amount of calcium**.

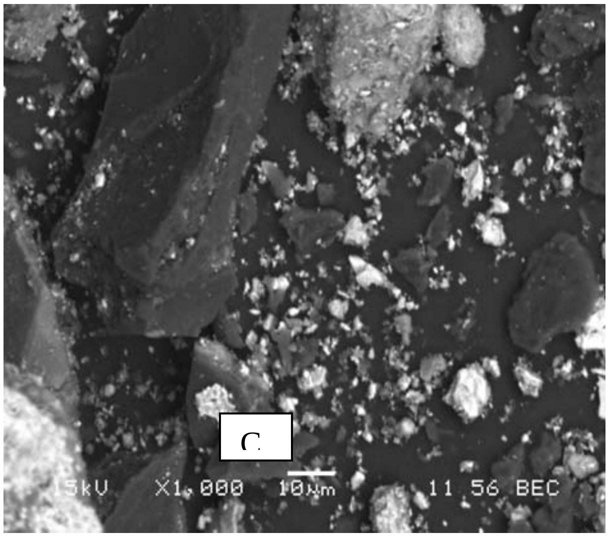


Fig IV.8C: **High iron bearing carbon particle.**

Element	Wt%
Fe	39.83
C	57.19
Ca	0.73
Si	1.26

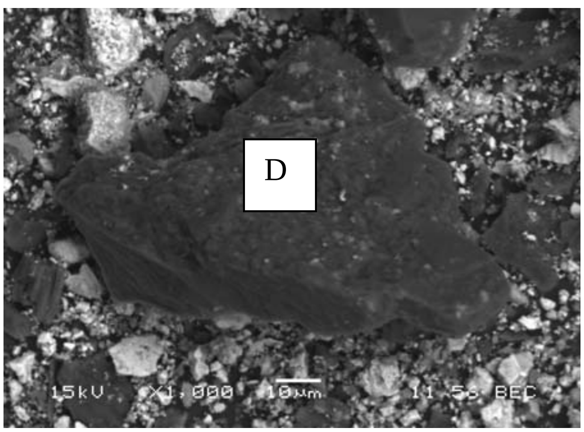


Fig IV.8D**: A carbon particle (unburnt coke) In flue dust.**

Element	Wt%
C	97.24
Al	0.70
Si	1.19
Fe	0.51

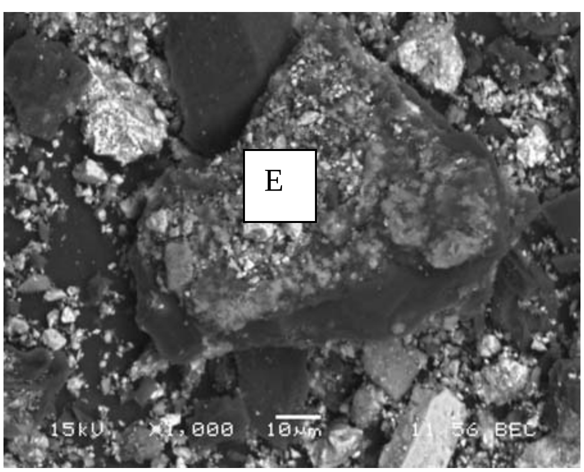


Fig IV.8E: **A carbon particle (66.7%) containing elements like iron (17.8%) and silica (6.1%)**

Element	Wt%
Ca	2.09
Fe	17.82
Si	6.10
Al	3.82

4B. Steel Making Shop/ Furnace (SMS)

The open-hearth furnace was the main means of steel making process accounting for about 75% of total global steel production. The first commercial unit utilizing pure oxygen blown from the top in a converter vessel was established in Lunz (Australia). The next two decades saw wide acceptance of this process, its improvements and optimization. By 1960, 13 million tones capacity of LD converter was built. It progressively increased to 75 million tones. In the late seventies, the major efforts were concentrated on the improvement in equipment and control techniques. The present BOF capacity including all its variants is about 725 million tones in the world.

In India, the crude steel production through open-hearth process was 78% in 1950 and BOF was nil. In 1994, share of BOF in the integrated steel plant rose to about 73%. The potential of oxygen steel making process was recognized quite early in India and soon after its commercialization the process was adopted at Bokaro steel plant, Durgapur steel plant, Bhilai steel plant, the units under SAIL, the Tata steel and Visakhapatnam steel plant. Today BOF route accounts for about 70% of the crude steel produced in the integrated steel plant.

Process Technology

Primary inputs in conventional BOF are hot metal from blast furnace and the scrap. The scrap proportion in conventional BOF is restructured to 20-30% of the total charge. In Bhilai Steel Plant, the steel was produced by using Twin Hearth Furnace and BOF process. Steel melting shop-I produces a wide range of steel. 4 Twin hearth furnaces in SMS-I replaced 10 open hearths. In SMS-II, through continuous casting, slabs & blooms are made after removal of LD slag and refinement of hot metal. After modernization, SMS-II is designed to produce 1.8 million tones of cast steel per year.

The LD- vessels at Bhilai Steel Plant are eccentric in shape. After the vessel is pre-treated to a white heat, it is ready to take the charge. The LD section is provided with overhead hot metal charging cranes for charging the hot metal in the to the converters, semi-portal scrap charging cranes, a gas cleaning plant to clean the LD gases from dust and to let the clean gas to the atmosphere. Each converter is having a tilting mechanism, for oxygen lances and the lance lowering and rising mechanism arrangement. 6 bins to store the raw materials, a scale car to collect the raw materials from the bins, to weigh and charge them into converters through the chutes provided in the hood above the converters. The charging starts with the addition of a few hundred kilogram of calcinated lime or dolomite through the overhead chutes which protect the lining of the converter. The tip of the lance is usually adjusted to remain about 100160 cm above the top of the bath. Oxygen of 99.5% purity and at a pressure of 10-12 kg/ cm^2 is blown into the bath at the rate of 7,000-10,000 Nm^3/ hr. Immediately ignition takes place and preferential oxidation starts. A chemical reaction occurs, where the oxygen reacts with carbon and silicon generating the heat necessary to melt the scrap and oxidize impurities. The entire blowing cycle is divided into three phases.

Phase-I: During the initial phase of oxygen blow, the main reactions in the metal phase are the oxidation of majority of the silicon in the hot metal and a major fraction of manganese. Iron is also oxidized to the slag with gradual build up of iron oxide. The temperature of slag during the initial phase is substantially higher than the metal heat. As blowing proceeds, the temperature gradient decreases. The lime dissolution rate is very high during this period and the slag phase remains in homogenous liquid range because, the concentration of both has not crossed into the heterogeneous dicalcium silicate region of the CaO-SiO_2 –FeO system. The de-carbonization rate is very slow at the start of the phase-1 and gradually increases as silicon is eliminated.

Phase-II: In the start of phase-II, the de-carbonization rate of Iron droplets in the emulsion begins to increase and the slag begins to foam. The iron oxide level of slag normally decreases and the liquid slag cross into precipitation range of dicalciium silicate. During this peak de-carbonization phase, the maximum slag foaming occurs with the probability of slag flowing (slopping) from the converter. The de-carbonization rate reaches at the peak and become primarily dependent on oxygen supply rate. During this stage the lime dissolution rate slows down and fluorspar or Mn-ore briquetts are helpful in further lime dissolution.

Phase-III: This stage begins when the de-carbonisation rate starts to drop and the foam begins to collapse due to lower rate of co-generation in the slag metal droplet emulsion. During further blowing, the composition of slag changes within the heterogeneous range of dicalcium silicate. The iron oxide level of the slag begins to increase again, and this results in an increased lime dissolution rate. The slag concentration approaching its final end point is primarily determined by the amount of lime added. The concentration range of final slag may lie between the saturation range of dicalcium silicate and that of lime.

The following reactions reveal that the removal of silicon is quite fast and is more or less complete in about 6-7 minutes after the commencement of blow. Manganese comes down concurrently with silicon up to a certain point and it remains for the rest of the blow except that some reversion may take place towards the end of the blow. Carbon and phosphorous oxidize together and the process of oxidation starts after a few minutes.

Some typical reactions taking place in the converter are as follows:

$Fe+[O]=FeO$	$CaO+SiO_2=CaSiO_3$
$2(FeO)+1/2O_2(g)=Fe_2O_3$	$[Si]+2(FeO)=SiO_2+2Fe$
$[C]+[O]=CO(g)$	$[Mn]+[O]=MnO$
$C+(FeO)=CO(g)+Fe$	$[Mn]+(FeO)=MnO+Fe$
$[Si]+2[O]=SiO_2$	$(MnO)+(SiO_2)+1/2O_2=MnO_2.SiO_2$

4B.1. Waste from SMS-II

From both the steel making shops of BSP, a variety of waste are being generated as shown in Table 4.4. However only LD slag was characterized and processed. **(fig IV.9)**

4B.1.1 SMS Slag (LD Slag)

4B.1.1.1. Generation process of SMS slag

The blowing of oxygen into the furnace is continued for about 20minutes after which the end point (0.04%) carbon level in the bath is reached which is characterized by the scrap decrease in length of the flame issuing out of the converter mouth. The converter is tilted and the steel is first tapped through the tap hole into the ladle kept on the steel transfer car. Then the converter is fitted to the opposite side and the slag is run off into the slag pots. From the above, it is understood that the functions of BOF basically are to remove impurities like silicon, manganese, phosphorous and carbon and to a lesser degree sulphur with the help of oxygen. The oxidation products involving all elements other than carbon leads to acidic slag which dissolves the lime added resulting in a basic slag having basicity > 3.0.

Table 4.4: Input & output of SMS-II

SMS-II			
Mixer metal	1063 kg	Concast slab	1000kg
Scrap	97kg	Skill & spillage	20kg
Fluxes		LD slag	220kg
Cacined lime	109kg	LD dust	100kg
Manganese ore	40kg		
Nail chiller, petroleum coke etc	5kg		
Ferro alloys			
Ferro manganese	3kg		
Ferro silicon	2kg		
Aluminium	5kg		
Silico manganese	2kg		
Others	1kg		
Oxygen	$74NM^3$		

Electricity	67KWH		
Mixed gas	111KCal		
Tap to tap time	18-22 minutes		
Blow time	48-75 minutes		

4B.1.1.2 Characteristics of SMS Slag

Physical characteristics

The nature, density and porosity of SMS slag is given in Table 4.5. LD slag appears grayish black and less porous.

Table 4.5: Physical properties of SMS slag

Type	Nature	Bulk density	Porosity
LD slag	Hard, massive and compact	3.645	0.009
LD slag	Porous	3.373	0.026

After crushing in jaw crusher, some metals come out which are too hard to be crushed. The physical properties of that metal is given below in Table 4.6.

Table 4.6: Physical properties of SMS slag

Type	Wt of dry sample(W_1)	Wt of sample in water immersion(W_2)	Bulk density
Flat	4.07	3.57	8.12
Irregular	4.69	3.93	6.13

Table 4.7: Determination of grain density of LD slag

Size in micron(μ)	W_1(Wt of bottle)	W_2(bottle +sample)	W_3(bottle+ sample+water)	W_4(bottle+ water)	Density
1000	44.54	46.27	112.12	109.90	3.39
500	46.12	47.92	146.78	145.51	3.37
250	13.15	14.62	24.09	23.06	3.53

125	13.32	14.79	24.18	23.14	3.34
75	13.38	14.50	24.12	23.35	3.20
37	13.13	14.33	23.92	23.20	2.27
<37	13.15	14.24	23.64	23.06	2.13

The slag samples were classified using different ISS sieves. In case of LD slag, 1000, 500, 250, 125, 75 and 37 micron sieves were being used. The size analysis of LD slag is being shown in Table 4.8 and the percentage distribution pattern of the sample is shown in Fig IV.10.

Table 4.8: Size analysis of LD slag

Size in micron	Wt	Percent wt	Cumulative
1000	68.99	17.84	17.84
500	129.84	33.59	51.43
250	120.19	31.09	82.52
125	21.46	5.55	88.07
75	20.02	5.18	93.25
37	11.02	2.85	96.10
<37	15.00	3.88	99.98

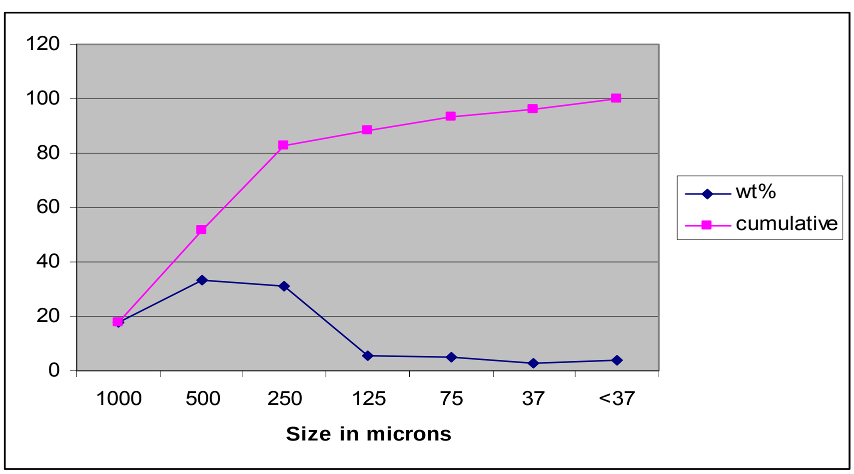


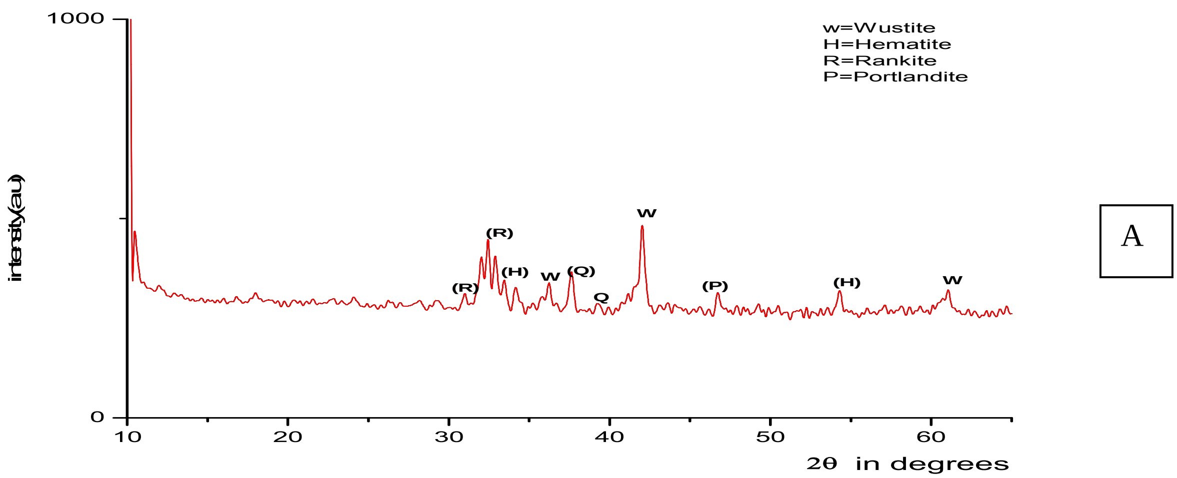
Fig IV.10**: Size analysis graph of LD slag**

The size analysis graph reveals that the heavier fraction constitutes around 905 of the total weight.

From this it is inferred that metals are concentrated in this fraction.

Mineralogical characteristics

LD slag shows comparable mineral phases such as portlandite [Ca $(OH)_2$], Hematite (Fe_2O_3), Wustite (FeO), Magnetite (Fe_3O_4) and quartz (SiO_2) and Rankite ($Ca_3Si_2O_7$) determined from XRD pattern (Fig IV.10). However, in LD slag portlandite dominates. Portlandite is a hydroxide phase formed due to alteration indicating thereby prolonged exposure of LD slag to atmosphere. The differential reflectivity of wustite under microscope, identified in XRD, may be because of significant amount of other cations such as Mn, Mg, Ca and Si in the structure. The SEM analysis of LD slag brings out two main phases: (i) Silica saturated (silicates) and (ii) RO saturated (ferrites). The calcium silicate phase is found to contain a combination of elements like Mg, Fe and Mn in its lattice in various proportions. These silicates characteristically occur in form of rosette up to 1mm size. A cid Bessmer slags reported by Goldrig and jukes (1997) show similar microtexture. Dicalcium silicate, another species, present in minor amount , is close to Ca2SiO4, with significant substitution of Si by P. The RO saturated phase consists mainly of (Fe, Mn) O. Some of these phases are calcium ferrite with minor Si, Mn and dicalcium ferrite with minor Si & Mn.



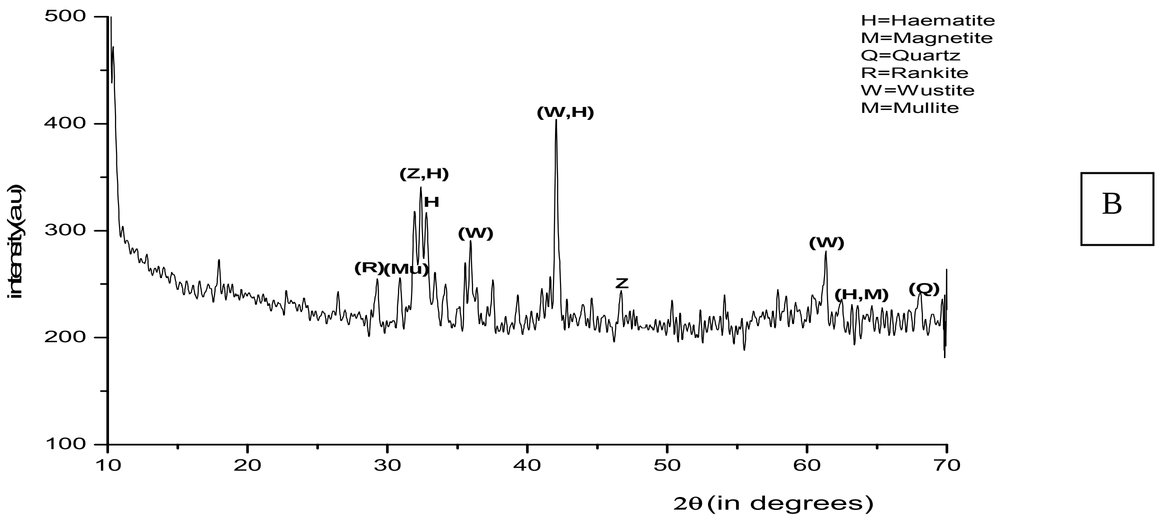


Fig IV.11**: XRD analysis of LD slag**

Optical micrographs of LD slag

The crystalline textures vary from dumbbell shaped crystal to circumform skeletal crystals. Microscopic characteristics of dominant phases are discussed below.

1. **Metallic Fe-phase**:-

Most of the metallic Fe-particles appear in large size (>125micron), fine globules are very uncommon (Fig IV.12C). They either composed of a single metallic phase or with thick or thin glassy incrustation (Fig IV.12E & C). Occasionally they exhibit flow structure enclosing glassy phase (Fig IV.12D).

2. **Iron-rich phase**:-

The iron rich phases are mostly of secondary Wustite (Fig IV.12B) and they are irregular in shape (Fig IV.12A). Wustite, partially oxidizing to hematite along the octahedral planes is a common feature. Though Ca-rich phases are abundant in LD slag as evident from SEM analysis but in optical microscopy they were not traced.

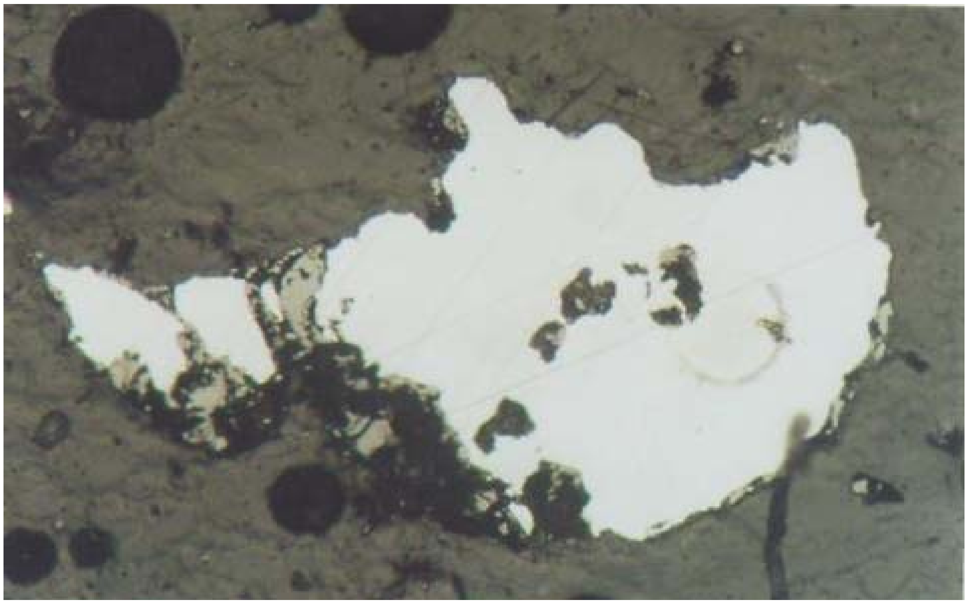


Fig IV.12A**: Large iron metal grain showing irregular boundary.**

Fig IV.12B: **Dumbell shaped iron metal-small grains of wustite.**

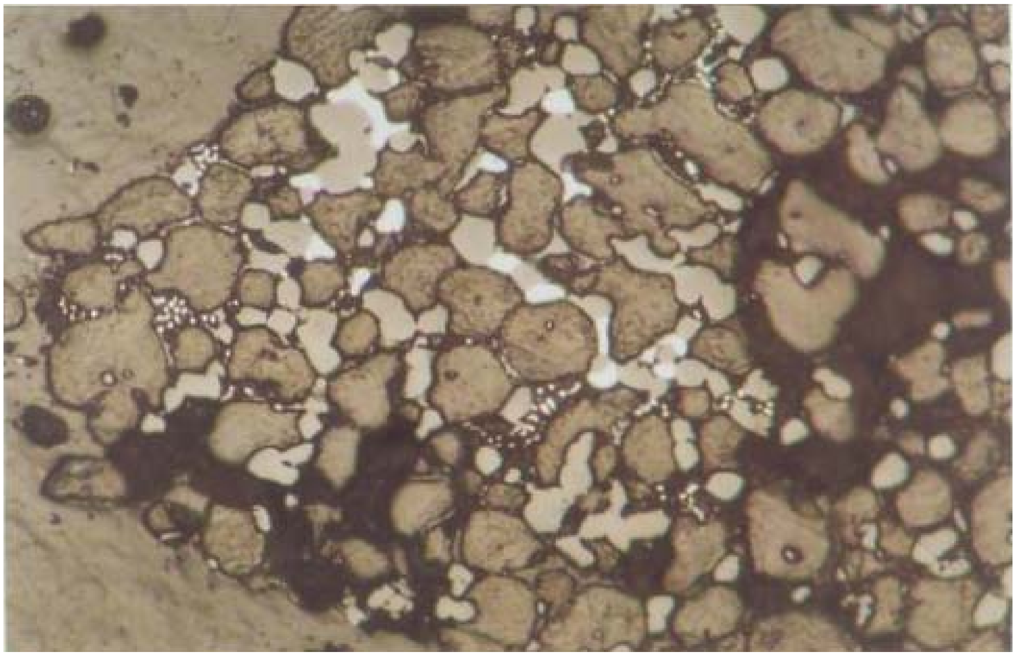


Fig IV.12C: **Cluster of circular slag particles with small wustite and metallic prills occupying the intergranular face of slag. X 100**

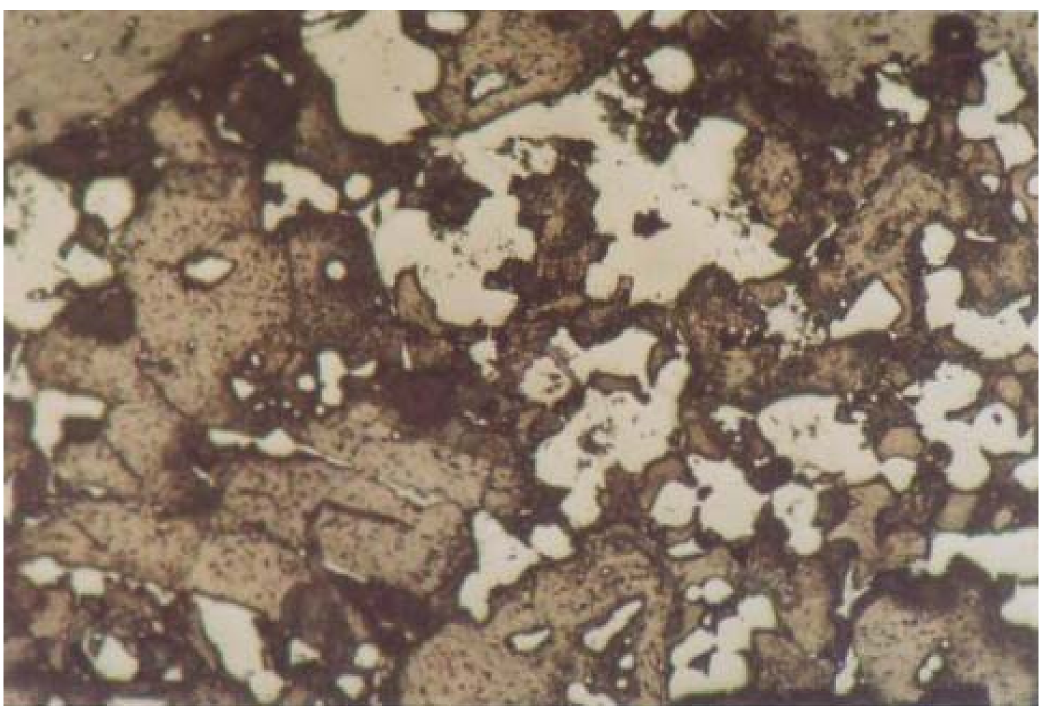


Fig IV.12D: **Irregular shaped wustite grain associated with slag grains. X 100**.

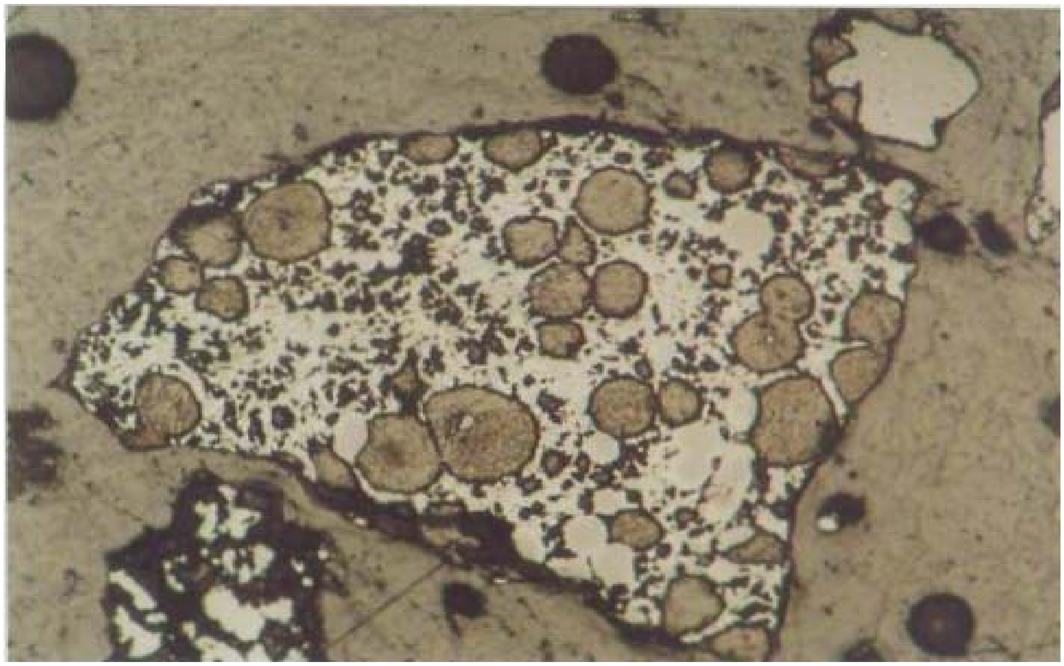


Fig IV.12E: **Ovoidal grain of slag occurring in association with wustite grains. X 100.**

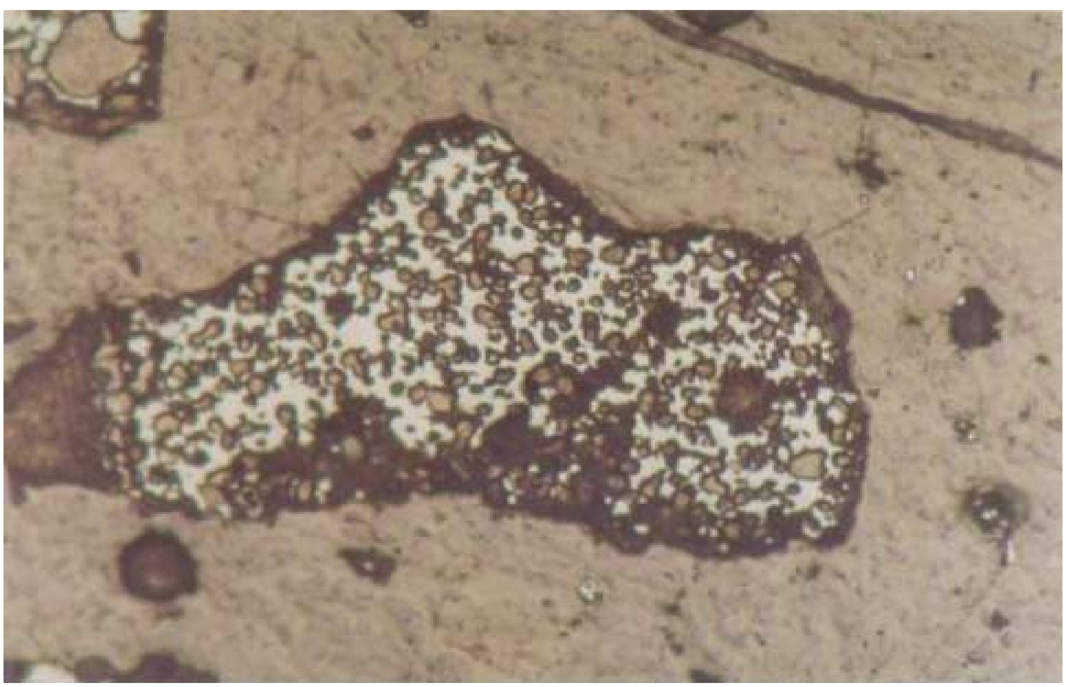


Fig IV.12F: **Fine inclusion of slag grain within wustite. X 100**.

Chemical characteristics

Compositionally LD slag is high in calcia and is shows lower incidence in comparision to THF slag. The sample of LD salg was ground to different size fractions, viz., 1000micron, 500micron, 250micron, 125micron, 75micron, 37micron and <37micron to know the distribution pattern of elements so as to study its sintering characteristics. More or less equal level of distribution is observed in allthe size fractions (Table 4.9)

Table 4.9: Major & minor element distribution in various size fractions of LD Slag

Size(µ	FeO	SiO2	CaO	MgO	MnO	Al_2O_3	TiO_2	P_2O_5	S
1000	26.50	12.99	45.35	6.95	3.66	1.60	0.84	1.80	0.13
500	26.58	13.90	43.51	8.34	3.67	1.50	0.80	1.69	0.12
250	25.23	14.43	44.18	9.31	3.49	1.47	0.79	1.78	0.11
125	25.28	14.06	42.49	9.33	3.46	1.67	0.79	1.69	0.12
75	26.77	14.00	40.17	8.73	3.52	1.79	0.76	1.67	0.12
37	24.45	15.75	41.06	9.94	3.27	2.01	0.77	1.73	0.12
<37	26.29	15.35	39.33	9.04	3.47	2.09	0.78	1.70	0.12

Trace elements (in ppm)	
Zn	7.05
Cr	460.16
Co	2.50
Zr	439.77
U	1.02
Th	10.04
Ta	33.51
V	13.33
Y	10.04
Pb	2.97

SEM Analysis of LD slag

Unlike optical microscopy where light is the source for image formation, in electron microscopy, the image formation is due to the scattering of electron beam scans over the sample. In general this study: i) brings out the size, shape and micro morphology of minerals and ii) their textural patterns. The SEM analysis of flue dust is given in Fig IV.13(A-D)

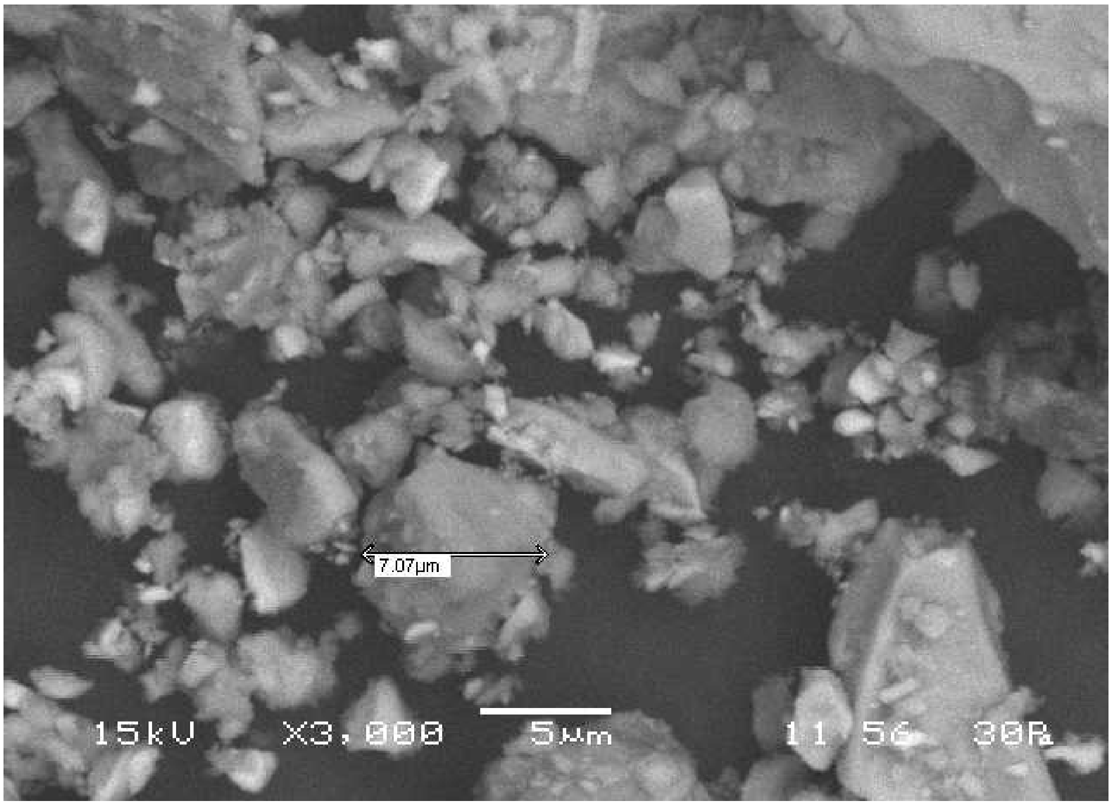


Fig IV.13A: **SEM photograph of LD slag using SEI technique.**

The SEM analysis of LD slag using secondary electron imaging technique shows some of the grains are euhedral, some are partly subhedral & rest are anhedral in shape. Some grains are angular in shape. The average grain size of the sample is found to be 7.07µm.

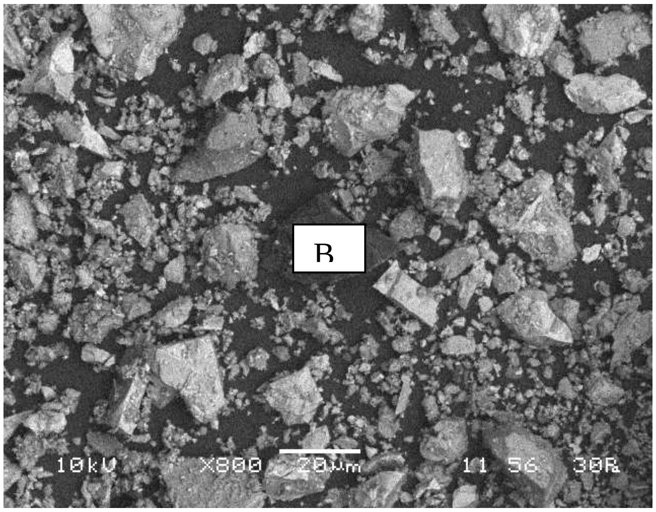


Fig IV.13B: **Calcium silicate crystal**.

Elements	%Weight
Calcium	81
Silicon	18.97
Probable phase: $CaSiO_2$	

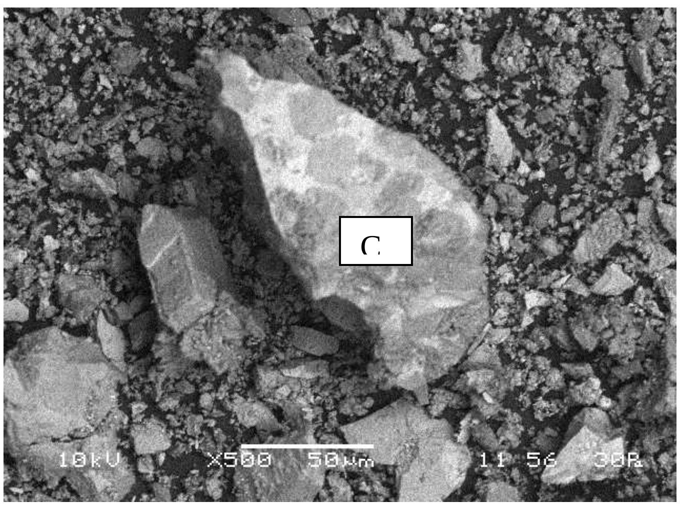


Fig IV.13C: **Dicalcium (Mg, Si, P) ferrite**

Elements	%Wt
Calcium	59.82
Iron	25.39
Phosphorous	2.29
Magnesium	1.79
Silica	10.71
Probable phase: Dicalcium ferrite contributing 2.3% of phosphorous.	

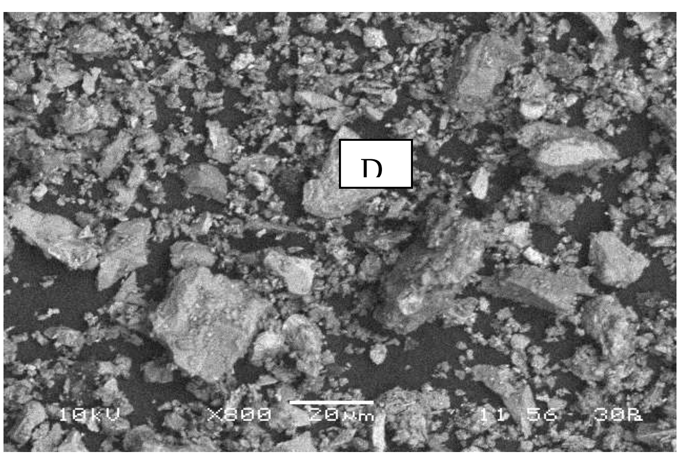


Fig IV.13D: **Calcium magnesium ferrite with silica**

Elements	%Wt
Calcium	31.49
Magnesium	13
Iron	51
Silica	4.5%
Probable phase: Ca, Mg (Si) ferrite	

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The correlation coefficient matrices presented in Table 4.10 show that iron and silica in LD slag are negatively correlatable while iron shows positive relation with magnesia. This is probably due to the development of some Fe-Mg spinel phase. Similarly a positive relationship between alumina and titanium is observed thereby indicating that Al-Ti spinel phase could also develop in this system.

Table 4.10:Correlation coefficient matrices between major & minor elements of LD slag.

	FeO	**SiO_2**	**CaO**	**MgO**	**MnO**	**Al_2O_3**	**TiO_2**	**P_2O_5**	**S**
FeO	1	-0.71	0.41	**0.67**	0.07	0.44	0.36	0.26	0.24
SiO_2		1	0.01	0.53	0.06	0.47	0.70	0.16	0.57
CaO			1	0.30	0.28	0.11	0.47	0.03	0.31
MgO				1	0.15	0.22	0.19	0.28	0.13
MnO					1	0.11	0.11	0.23	0.26
Al_2O_3						1	**0.63**	0.12	0.37
TiO_2							1	0.20	**-0.70**
P_2O_5								1	0.12
S									1

Chapter- V

UTILIZATION OF WASTE

UTILIZATION OF WASTE
Present Status and Future Prospects

In an integrated Steel plant for every tonne of finished steel about 5 tonnes of input materials of iron ore, coal, fluxes, Mn ore, Ferro alloys, etc are required and nearly 3.5 tonnes of solid wastes like slag, dusts, sludge, fly ash etc are generated. Collection, transportation and dumping of these wastes are very expensive warranting large space on land. The volume of waste generated in a steel plant is an indicator of its state of efficiency/ inefficiency in operation. Reduction of waste generates and gainful utilization & recycling of these wastes not only improve the economics of operation but also prevents degradation of eco-system to maintain an amicable environment in and around the steel plant.

In terms of quantity, BF slag, SMS slag and fly-ash-the three important solid wastes constitute about 94% of total waste generated at BSP. Smaller quantities of under size raw materials are generated during the sizing and screening process of various raw materials. These materials may informally be considered as waste, which can be reused as sinter feed. Botha (1994) has reported the recycling of waste via the sintering process. Even some researchers like Heiss et al (1993) has reused dust in form of hot briquettes.

5.1 Present Status of solid waste in BSP

Management of solid waste is a great challenge to the smooth operation of the plant at Bhilai because the actual generation is more than the computed norm. At base capacity of the plant (5.0 Million Tonnes), Bhilai Steel Plant should generate 2.0 million tones solid waste but on an average of last three years (2004-2007), BSP has generated about 2.7 M.T of solid waste per annum for a production level of 5.0 million tones of crude steel. Out of this 24.8% was sold, 14.2% was recycled and rest 60% was dumped in dump yards as shown in the following pi-chart(Fig.VI.1A). There are 30 different solid waste materials generated in the plant. However, the major solid waste types, sold, recycled, and dumped considering an average of last three years (from 2004-07) covered under study have been shown in Table 6.1a to Table 6.1d.

Status of major sold waste generated from iron making (Fig VI.1C) and steel making furnaces (Fig V.1B) are shown in pi-charts in the following pages.

Flu dust normally recycled through sinter routes. In BSP, around 50% of total generated Flu dust is being recycled because they contain less than 1.7% of alkalies. Flu dust contains around 30% of unburnt carbon and appreciable iron content. Dumping of this material causes loss of revenue on both counts.

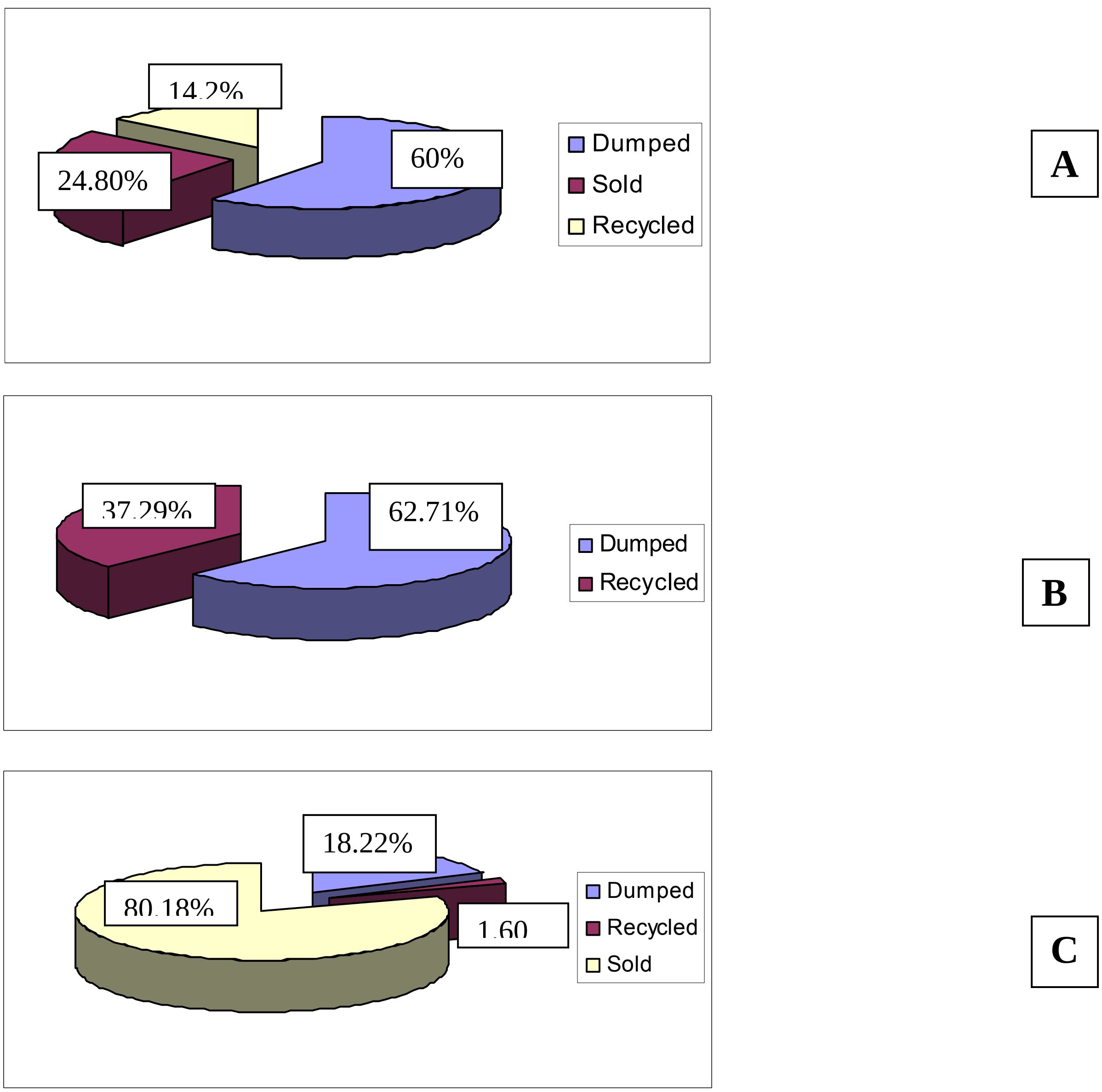

Fig.VI.1**: Solid waste status in BSP**

A. Major solid waste; **B.** Solid waste from Steel making

C. Solid waste from Iron-making

Table 6.1a: Year wise quantitative status of BF Flu dust

Year	Generation (T)	Sale (T)	Recycle (T)	Dumped (T)
2004-05	98812	1267	46241	51304
2005-06	67596	19660	9123	38813
2006-07	109049	21647	33141	54261

LD slag is presently processed by Scrap and Salvage Department (SSD) with a view to recover the steel scrap. The slag pieces (+25-50mm) of BOF slag are picked up annually for sale to the railways. Despite this ready demand, the material is not treated and processed as a valuable by-product because of some inherent problem. The oversized and undersized BOF slag is used for road making.

Year wise quantitative status of both THF and LD slag is given in Table 5.1b & 5.1c.Some quantity of such slag are recycled in Blast Furnace due to its low alumina and high calcium/magnesium content. However the problems in utilizing the slag for other purposes are described below separately.

Table 6.1b: Year wise quantitative status of THF Slag

Year	Generation (T)	Sale (T)	Recycled (T)	Dumped (T)
2004-05	137024	-	6998	130036
2005-06	260388	85	208310	51993
2006-07	149823	-	-	149823

Table 6.1c: Year wise quantitative status of LD Slag

Year	Generation (T)	Sale (T)	Recycle (T)	Dumped (T)
2004-05	238090	-	98898	141192
2005-06	252227	-	75202	177025
2006-07	260322	208300	85	9000

A lot of waste in the form of fly-ash is generated (Table 6.1d) from Thermal power plant which has been an age old lingering problem. The status of this waste is shown in pi-chart below (Fig.VI.2). As one can see more than 88% of it is dumped. Long since people have been trying to utilize it (Torrey, 1978; Kumar, 1998). In BSP, only 5 to 6% of fly-ash (Table 6.1d) was utilized otherwise most of it is being dumped.

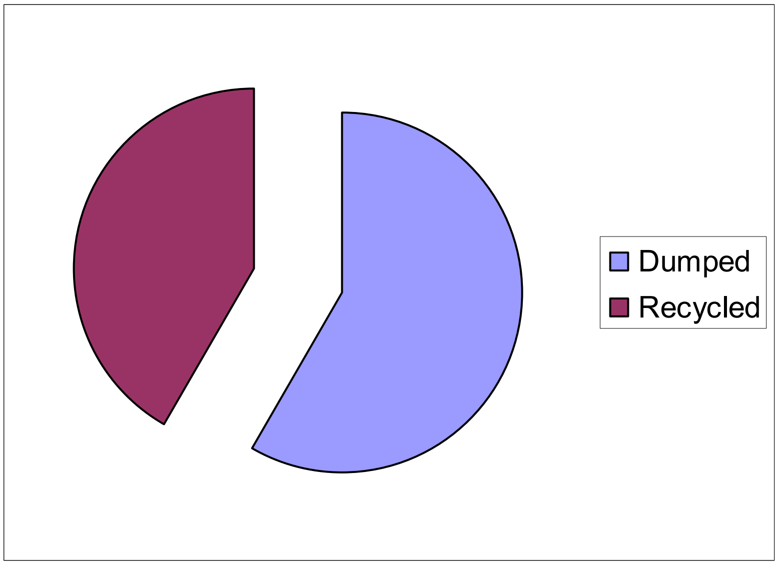

Fig.VI.2----: Solid waste status of Captive power plant, BSP

Table 5.1d: Year wise quantitative status of Fly-ash.

Year	Generation (T)	Sale (T)	Recycled (T)	Dumped (T)
2004-05	58648	-	26000	32648
2005-06	31500	-	24538	6962
2006-07	36322	-	2080	34242

5.2. Problems on utilization of BSP solid waste

Though some of the BSP solid wastes are recycled/ reused in various ways (Roy et al.), a considerable quantum of them is left out as dumps because of their unsuitability for further utilization. Efforts have been made by several workers to characterize these wastes in-depth (Suito et al., 1977; Hagni and Hagni, 1991; Karakus and Hagni, 1991; Goldrig and Jukes, 1997) and to recover some of the valuables from them (Franault, 1982; Kurbatskii et al, 1992; Strohmeier, 1993; Reddy et al, 1996) but optimum utilization has been difficult because of some inherent problems. Some such problems on utilization of solid waste samples generated from its different unit under reference are discussed below. The main objective is to focus the trouble shooting phases present in them.

5.2.1 Problems on utilization of BF waste

BF crystalline slag is usually used in road making while BF flue dust is being dumped and hence studied in some detail. The different phases identified in BF flu dust are already mentioned in chapter III.

Some harmful components like Pb and Zn, as reported from many parts of the world restricts its reuse in Blast furnace. Even some workers have established processes to recover Pb Aand Zn values from dust (Doremieux et al, 1979; Stamatovic and Themelis, 1993; Imris, 1995; Peek et al, 1995). These are mostly derived from recycled scrap. However, BSP flue dust is free from these elements as only 0.7% scrap is added as one of the input materials to Blast furnace(Table 4.1). The flu dust of BSP is being recycled as sinter feed due to comparatively low alkali content (Na+K oxides=1.70), unlike the flue dust of RSP whch contains a higher percentage of alkalis. The presence of these alkalis attributed to limestone and coke added as input to Blast furnace. Alkali elements often accumulate in the Blast furnace and corrode the refractory lining. Reuse of BF dust is still an unsolved problem in many countries of the world (Fosnacht et al, 1981). Attempts have been made to minimize the level of alkali from flu dust by different beneficiation techniques but total elimination of potassium is not possible in view of its complex association with other elements.

5.2.2 Problems on utilization of SMS waste

Only a part of SMS slag is recycled as input material into Blast furnace because of two following problems: i) the slag is of calcic composition and is volumetrically unstable being liable to expand and disrupt with time & ii) it contains phosphorous which restricts the reuse in any furnace. Reforming of BOF slag for synthetic fluxes has been reported by Ryu et al(1995). Broad utilization of metallurgical slag has been reported by Kurbatskii et al, (1992).

LD slag contains portlandite. This material is well known for its ease of hydration causing local microcracking. The hydration gives rise to localized volume increase that widens that widens the cracks and forces aggregates of the altered slag apart. Okamoto et al. (1981) found that hydration was effected initially by the formation of a surface layer up to about 50 micron in thickness that eventually exfoliated. When hydration proceeds further, cracks formed in the particles that led to disintegration. LD slag is more prone to volumetric instability than BOF slag.

SMS slag has phosphorous as the deleterious impurity with P_2O_5 content going as high as up to 5.00% (BOF having more P_2O_5 than LD slag). These are mostly attributed to manganese ores used in the furnace. Higher level of P_2O_5 content in SMS slag is due to higher proportion of manganese ore input. It is not possible to remove P from the slag by acid leaching, carbon reduction and gravity separation, high gradient magnetic separation and flotation carbon and non ferrous metals by size classification through hydro cyclones has been attempted by some workers (Toda et al, Schriefer, 1997). It is reported that Zinc and lead present in the blast furnace flue dusts may be recovered by size classification, flotation and acid leaching or by selective reduction under reduced pressure (Doemieux et al, 1979). However, total separation of valuables from these waste and recycling them together as sinter feed or as briquette have been least attended too.

5.3.1 Beneficiation of Metallurgical dusts/ sludge

Most of these solid wastes from Iron and steel making furnaces contain useful phases of iron, carbon, lime etc. which may be considered as reusable resources in steel plants. Many researchers in the past ; (Fosnalnt, 1982; Hay et al, 1993; Strohmeier, 1993; Rehmat, 1996; Reddy et al, 1996) have worked on recovery of iron and carbon values from BF dust but with limited success.

5.3.1.1 BF dusts/ sludge

The complete chemical analysis of the BF flue dust sample is given previously shown. The sample contains around 42.6% of Fe_2O_3 and carbon 31%. The high percentage of both unburnt coke and Fe-minerals show the abnormal accumulation of these elements in the flue dust sample. The BSP sample does not have appreciable amount of Na_2O and K_2O, for which it can be used in sinter making. The alkali elements are mainly contributed by limestone/ dolomite. However total replacement of limestone by Dunite in raw mix substantially reduces the alkali level (Formose et al, 1997).

The BSP sample however does not contain any significant amount of Pb and Zn as reported in flue dust samples from other parts of the world (Roy et al, 1998). The concentrations of environmentally hazardous heavy metals such as Ni, Cu, and Cd etc. are also low. The size analysis of the sample is shown in Figure III.5. The 50% passing size of the sample is found to be ≈250μm. The carbon values are mostly concentrated in the coarser fraction while the iron values in the finer fraction.

5.3.1.2 Utilization of Fly ash

Utilization of Fly ash as a building material has been largely attempted to (Nayak et al). Building industry, a fast growing sector is one of the key areas of infrastructure development. At present the building industries depend on the use of natural resources to fulfill the demand of construction materials in the country. Naturally occurring stone aggregates, gravel and sand are very popular for their use in building and road construction. Utilization of these materials is gradually restricted to save the destruction of landscape and valuable forest- lands and to check their impact on environmental degradation. Search for alternate material and utilization of various industrial solid wastes in construction industry is considered to be very important. Fly ash being a powdery material, its use in various building construction activities is limited. Conversion of powdery fly ash into lumpy aggregates is one of the methods for bulk use in various constructional activities. As early as 1957 and 1963 the use of fly ash in form of sintered lightweight aggregate pellets as construction material was initiated in UK and USA respectively. Since then the manufacture of sintered light weight pellet from fly ash and its utilization in mass concrete, construction for acoustic and thermal insulating building materials in seismic zones and arctic climates, masonry bricks and blocks, road and embankment have made significant progress. Many developmental activities have been carried out in commercial production of sintered light weight pellet for building material use from fly ash and other solid waste such as Fe-dust, LD dust, acetylene sludge, mineral fines etc. by adopting rotary kiln and continuous chain grate sintering system is well known in iron and steel industries for agglomeration of iron ore fines for blast furnace use.

Since a lot of literature is available on the utilization of fly-ash, only limited attempts were made to utilize this along with acetylene sludge and neutralization plant sludge for brick making. The details have been described under acetylene sludge.

Chapter- VI

SUMMARY AND CONCLUSION

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SUMMARY

An integrated steel plant consumes large variety and quantity of resources raw materials and energy for producing steel and in this process of conversion generates substantial quantities of solid, liquid and gaseous waste. The liquid and gaseous wastes are easy to handle while generation of solid waste at the rate of 1000kg/tonne of crude steel production poses the vexing problem of management. Most of the wastes are dumped in open low lying areas causing both disposal and environmental problems. Presently, the scenario of the waste management has undergone sea change due to increased pressure on industry from regulatory authorities to protect environment and sort out of the dumping predicaments, It is in this context, the industry is interested to reuse/ recycle these waste as much as possible. The solid waste generation, presently in Indian steel industry, is in the range of 600-1000kg/tonne and recycling rates vary between 40-70% which leads to higher production costs, low productivity and further environmental degradation. But for effective utilization at a reasonable cost, all these waste need to be characterized prior to further processing.

The production of steel at Bhilai Steel Plant involves several operations starting from raw materials feed like iron ore, coal, flux for production of hot metal in Blast furnace, conversion of hot metal into iron & steel and subsequent rolling of steel into finished products in the rolling mills. Besides, there are a number of auxiliary units like thermal power plant, acetylene plant, sinter plant, refractory units etc. to support the steel production in various ways. These units also generate different types of solid waste. The overall generation rate depends upon the quality of raw material and technology adopted for production. Out of several kinds of waste generated from different units at BSP, a few selective types were characterized in respect of their physical, mineralogical and chemical properties. Special geochemical affinity of certain elements in the waste in relation to mineral phases in the feed was looked into. Possible recovery of valuables from some of them and means of their optimum utilization was investigated. The study included the characterization of waste generates from metallurgical furnaces (both steel making & steel making) and thermal power plant.

The solid waste can physically be grouped into two categories: slag and dust/ sludge. Crystalline slag is hard, compact and occurs in lumpy form, while granulated slag and dust appear in powdery form.

6.1 Slag

Iron and steel making slag constitutes the major portion of solid waste at Bhilai Steel Plant. Because of high ash content of Indian coals, the slag generation from Blast furnace is high and its disposal leads to environmental problem. The slag generates from Steel melting shop II are hard, dense and contain portlandite, Wustite, hematite and rankite minerals. This slag has high basicity i.e. a good amount of calcium: magnesium ratio which can neutralize the siliceous/ acidic constituents of gangue in Blast furnace burden. But its high P_2O_5 content inhibits its large scale use. A SMS slag on average contains 14.43% SiO_2, 25% FeO, 41% CaO, 9.5% MgO, 3.5% MnO, 1.74% P_2O_5, and 2% Al_2O_3. The high phosphorous content in LD slag is attributed to larger manganese ore input into the converter.

Removal of phosphorous from SMS slag by any physical beneficiation technique is not possible as P2O5 is intricately mixed with other elements. Further, because of high calcic composition contributing to volumetric instability, expandability and disruptibility, the utilization of larger bulk of SMS slag is greatly impeded. Often granulated LD slag is being used as soil conditioner. By the addition of LD slag to soil, it is possible to achieve a proportional increase in soil's pH. This improves the quality of the soil and its productivity too.

6.2 Dust/ sludge

Generation of fine particulates begins from the very instance of arrival of raw materials till delivery of finished products. The steps of fine generation include ore crushing: material handling& transportation: operation at sinter plant, Blast furnace, steel making, rolling etc. In different high temperature operation, the hot gas laden with dust particles is cleaned for recirculation. During this cleaning process, the dust particles are removed from the gas by dry and wet scrubbers in the form of dust/ sludge. In Bhilai steel plant, dust/ sludge accounts for about 20% of total solid waste out of which 80% is generated during iron and steel making.

The dust/ sludge obtained and studied from different units of Bhilai steel plant can broadly grouped under four categories: i) Ferruginous + Carbonaceous waste ii) Ferruginous+ Calcium-rich waste iii) Alumino-siliceous waste iv) Calcium-rich waste. The detailed characteristics of these wastes are summarized below:

6.2.1 Ferruginous+ Carbonaceous waste

Amongst different types of waste generated from various units at BSP, the ferruginous waste tops the list. Some wastes are both ferruginous and carbonaceous in nature. These are mostly flue dust, GCP sludge and silicon mill sludge. The iron minerals in these wastes include hematite, ferrosilite. Gehlenite and quartz often occur as subordinate phases. Flue dust is rich in alkali and can't be recycled directly but the flue dust of BSP has less alkali content. So it can be directly used in sinter making. Carbon values from the flue dust can be recovered through flotation. The flotation tailing material if subjected to either Magnetic separation or Tabling gives a considerably rich Fe-product (63% Fe with 30 to 50% recovery) which contains both hematite & carbon and being relatively poor in alkali content, it can be blended with iron fines in sinter making.

6.2.2 Ferruginous+ Carbonaceous waste

The waste generated from steel making furnaces (SMS-I & SMS-II) are usually rich in both ferruginous (Fe=---) and calcium rich phases (CaO=40%). The iron rich phase includes magnetite, Fe-metal, calcium ferrite while calcite, portlandite forms the major calcium rich phases. This waste can't be directly recycled because of presence of both alkali (1%) and phosphorous (1.70) in appreciable amount. The iron value can be recovered from these wastes either through Magnetic sepatation(60% Fe with 82%recovery) or Tabling(65% Fe with 37% recovery). The resultant product would be suitable for recycling even in steel making furnaces via sinter plant.

6.2.3 Alumino-siliceous waste

Captive thermal power plants (CCP I & II) in BSP generate huge quantity of ash (fly-ash and bottom-ash) during combustion process for generation of electricity. The fly-ash is very fine and contains mostly aluminous rich (mullite) and siliceous (quartz) phases with minor magnetite and hematite minerals. A typical fly-ash sample mainly contains 51% SiO_2, 1.2% CaO, 30% Al_2O_3, and 3% Fe_2O_3. The use of fly-ash in brick-making, as pozzolanic material for cement, synthetic aggregates, mine stowing material etc. is well known. The fly-ash of BSP along with neutralization plant and acetylene plant sludge can be used in brick manufacturing. The iron rich phases from fly-ash can be effectively be separated through wet magnetic separation and be recycled to blast furnace via sinter plant.

The detailed mineralogical and geochemical studies carried out on solid waste of Bhilai steel plant has opened up a new vista for their utilization potential. This investigation has contributed in a big way towards enhancing the economy of Bhilai steel plant through waste utilization in eco-friendly manner. In fact, the so called waste can be treated as useful resource if its characristics and delineated, valuables are gainfully recovered and its proper utilization avenues are established.

Management of solid waste of BSP has two important objectives of national interest such as utilization of waste converting it into wealth through recovery of valuables and secondly minimization of the detrimental impact of waste generation on the ambient environment. This study is an attempt towards achieving this goal. It is the modest beginning and and its further pursuance will be rewarding in a big way in future.

CONCLUSION

The detailed mineralogical and geochemical studies carried out on solid waste of Bhilai steel plant has opened up a new vista for their utilization potential. This investigation has contributed in a big way towards enhancing the economy of Bhilai steel plant through waste utilization in eco-friendly manner. The detailed characterization of the waste samples leads to the following conclusions.

- After treatment, LD slag is suitable for cement manufacture and Iron can be recovered from it.
- If carbon recovery from fly ash is possible then it will not only reduce the fuel consumption in power plant but also useful in cement manufacturing and setting up an ancillary industry.

- These are not only low cost methods but wastes can also be utilised and the most vital factor is that these are eco-saving measures.

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